COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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Photo by Elwood M. Payne

New Hutchinson Power Station of Kansas Power & Light Co.

Adequate Power Seems Assured ▸

World Power Conference—II ▸

Trends in Boiler Design ▸

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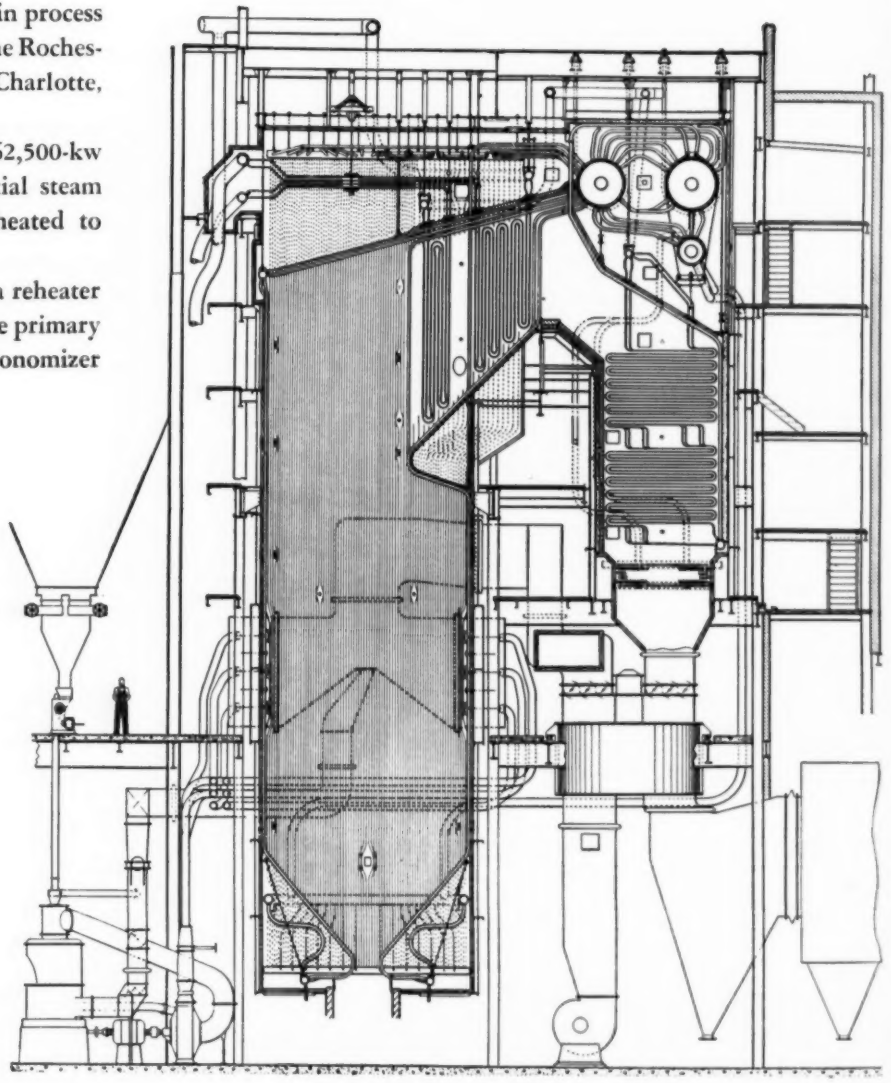
The furnace is fully water cooled, using closely spaced plain tubes except in the roof section, where finned tubes are employed. It is of the basket-bottom type, discharging to a sluicing hopper.

Pulverized coal firing is employed, using bowl mills and vertically-adjustable, tangential burners.

B-386



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September, 1950

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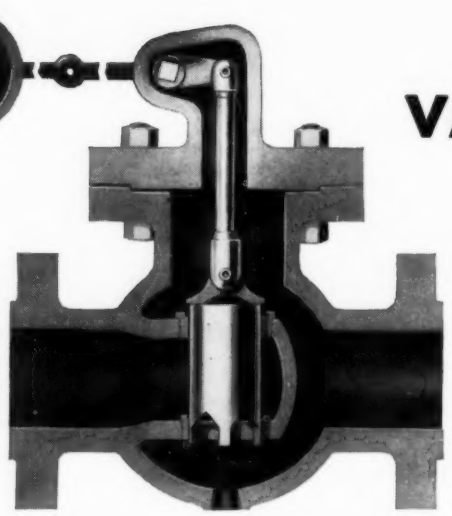

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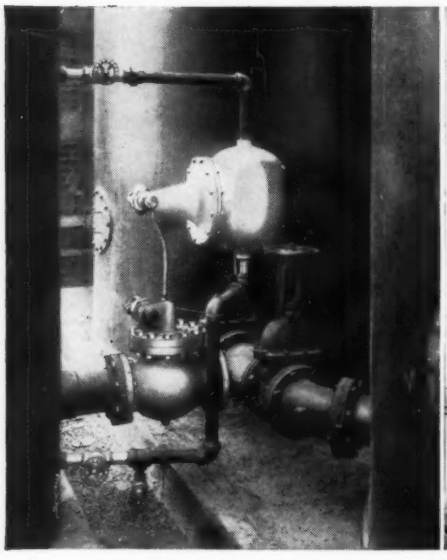

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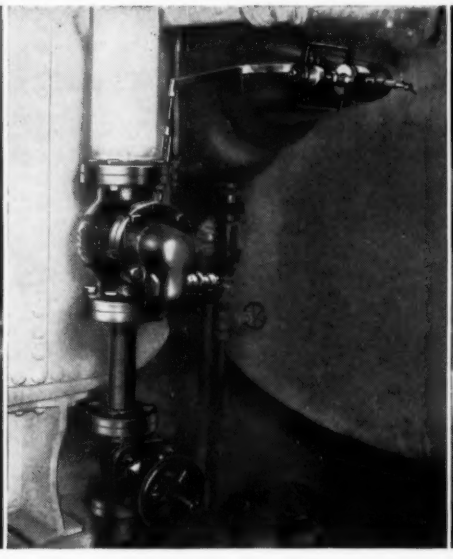
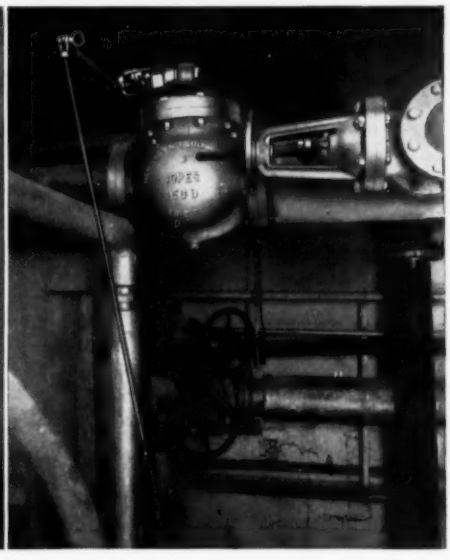


Flow of blow-down water from a flash tank is controlled by this float-operated COPES Valve.



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Editorials

The National Science Foundation

President Truman has recently appealed to appropriation committees of both the Senate and the House to make available funds for setting up the National Science Foundation in order that he may appoint its policy-making board of twenty-four persons to be selected from the fields of science, engineering, industry and agriculture.

The bill creating the Foundation was introduced a long time ago but was passed by the Congress late last spring, after lengthy hearings and finally emerged, despite some opposition, with provision for clearance by the F.B.I. of all persons associated with research projects. This precaution was not in the original bill, as it was then not considered to have appreciable bearing on national security, but revelations in the Fuchs case, and others, were responsible for its insertion. The bill carried an appropriation of $475,000 for the first year and 15 million per year thereafter. Research would be carried out at various universities and other institutions under sponsorship of the Foundation.

In making his request for the release of funds, the President mentioned national security as a pressing reason for getting an early start. From a long-range standpoint, this may be a valid reason, although it could have little immediate effect. The ultimate benefit to be derived from such a Foundation would probably be reflected in many fields of which engineering might well be one.

Compared with the vast Federal expenditures currently being made under the guise of education, the appropriation for the National Science Foundation appears insignificant; hence there seems little justification for its being held up by the Congressional Committees concerned.

Program Making

After listening to a series of technical papers at a large engineering meeting, one may be led to question whether quality has been sacrificed to quantity in the program making. In other words, authoritative and timely information rather than subject coverage should dictate in arranging a program. If nothing of an outstanding nature has occurred in a particular field, it might well be passed over in favor of another that warrants attention. This does not infer that most programs are lacking in some excellent papers, but these are often interspersed with others of mediocre caliber which are either too superficial or contain what may be termed a rehash of handbook facts.

To analyze this situation further one must go back to the invitation which initiated the paper and to the process by which it was prepared. The desire to have papers under the authorship of engineers of established professional prestige is quite natural, but it often results in the task being passed on to a subordinate who, knowing that no recognition may be forthcoming for his efforts, accepts the assignment with little enthusiasm. The product under such conditions is likely to be dull and unimaginative, notwithstanding that the subordinate may be technically capable and able to handle English as well as, or perhaps better, than his superior. Then again, in some organizations the contents of a paper may be dewatered for policy reasons. This, of course, is beyond control of the program committee but it often does detract from the interest of the paper.

Program-making agencies should recognize that a "big name" is not necessarily synonymous with a good paper; and that more encouragement might well be extended to engineers actively engaged in important work who have the desire and ability to write but lack the prestige often associated with an invitation to present a paper. Co-authorship is one solution.

As far as the writing itself is concerned, it is highly desirable that technical papers, aside from the prime consideration of presenting facts, have some intellectual challenge and show evidence of creative originality. Too often spontaneity is lacking and the paper becomes boring even to those most likely to be interested in its contents.

The foregoing comments are not aimed at any one society or group, but apply quite generally where the tendency is toward holding bigger and bigger meetings, sometimes to the annoyance of those in attendance.

New Capacity Shows Trends

Orders placed by electric utilities for steam generating equipment since the middle of June have exceeded the volume placed in any previous like period, and a glance at the specifications provides an index of current trends toward larger units, more general employment of high pressures and increasing use of reheat. The larger proportion of these units range in capacity from 500,000 to a million pounds of steam per hour with at least half employing reheat. Of those that do not, several are for areas of relatively cheap fuel. With few exceptions, mostly for existing plants, steam pressures of 1350 psi and above predominate, in contrast with a few years back when about half of the new jobs were under 1000 psi. While many of the units will employ 1000 and 1050 F total steam temperature, there is little indication of further rise until more experience has been gained with these maximum steam conditions in existing installations. One very large unit will employ forced circulation. The outstanding fact, however, appears to be the rapidly growing acceptance of the reheat cycle.

ADEQUATE POWER SEEMS ASSURED

A comparison of post-war growth in both power output and installed utility capacity with those existing during World War II indicates ability to meet the probable demands of an emergency. Thus far, in the post-war period nearly sixteen million kilowatts of new generating capacity has been added and another twelve million is under construction or projected. Also, reserve capacity has now attained what may be considered a safe margin.

THE present stepping up of defense measures, involving a greatly expanded military program, is certain to be reflected in the power demands in many sections of the country. Even though the Korean situation does not lead to a major conflict, these demands will be superimposed on the current power requirements of industry and thus raise the total more, perhaps, than would be the case in the early stages of an all-out war, when civilian commodity production would be limited and conversion would be in progress. Moreover, in the latter case military production would be around the clock and thus affect the electrical output more than the demand. Of course, as war production got into full swing, the electrical demand in some localities might also go up to an unpredictable extent, depending upon the allocation of orders for military supplies.

Postwar Load Exceeds War Peak

At least, this may be inferred from experience during World War II, which, perhaps, is the best criterion offered. In 1942, the first full year of the war, the total electrical output from public and privately owned utilities was approximately 186 billion kilowatt-hours. In 1944, the peak year of war production, this had increased to 228 billion kilowatt-hours. This represented an increase of 23 per cent which, of course, was exclusive of the energy furnished by other than utility plants. Yet for the twelve months ending June 30, 1950, under peacetime conditions, the total utility output was in excess of 304 billion kilowatt-hours, which was 33 per cent over that of the peak war year, or 63.4 per cent over that of 1942.

At the time the United States entered World War II late in 1941, the installed electric utility capacity was approximately 42,405,000 kw, which included both private utilities and those publicly owned. At the time a very considerable expansion program had already been initiated. However, there were many cancellations of orders for new generating equipment, at government direction, because of military requirements that necessitated allocations of both materials and manufacturing facilities, and only the most urgent new power construction was permitted to proceed. Despite this, the private utility industry was able to meet practically all essential war demands made upon it for power, with a minimum of curtailment of other services. This was accomplished through extensive system interconnections, by effective allocations and by the cooperation of all concerned. By the end of the war the installed capacity had increased to between 49 and 50 million kilowatts, about 60 per cent of the increase being in the private utility plants, and remained at approximately that figure for considerably more than a year thereafter.

Obviously, the foregoing figures are exclusive of industrial power plants and those installed in government-owned munitions plants. Many of the latter, however, installed steam generating equipment and depended upon utility service for electricity. This was because of the heavy demands of the Navy and Maritime Commission for steam turbines which taxed to the utmost the manufacturing capacities of turbine builders.

Post-war demands for power, following a brief period of reconversion, exceeded all expectations as a result of pent-up demands for consumer goods, and for a while resulted in dangerously low capacity reserves in certain sections of the country. This was inevitable and no fault of the utility managements, for although orders were immediately placed for additional equipment to replace those previously cancelled by order of the government, many months were required to produce large generating units. However, because of the extensive system interconnections that had been made before and during the war, the situation was met in most localities with minimum inconvenience to users of electricity, pending the installation of the new, more efficient capacity.

Sixteen Million Kilowatts Added

The first effects of this program began to be felt in 1947, and during the past five years nearly sixteen million kilowatts of new capacity has been added, bringing the total as of June 30, 1950, up to 65,596,000 kw, according to reports from the Federal Power Commission. This includes about nine million kilowatts of reserve capacity. Judging by scheduled completions, the total by the end of the present calendar year should reach 67,500,000 kw. This is represented graphically by Fig. 2, which shows the growth in capacity since the war to be more than twice that during the war period.

The present construction program should add another twelve million kilowatts by the end of 1952, providing international developments do not bring about a repetition in suspensions of new construction. Even if they do, the country would be in a much better position from the power supply standpoint than it was at the time suspensions were evoked during the late war. Moreover, the scheduled construction program is being amplified by many new proposals, and orders for additional new equipment during the past months have been heavy, and continue so.

Incidentally, the Federal Power Commission also reports that, as of June 30, 1950, the combined utility and industrial plant electric generating capacity was 79,315,000 kw.

As was pointed out recently by L. V. Sutton, president of the Edison Electric Institute, in a letter to W. S. Symington, chairman of the National Security Resources Board, some thirty million kilowatts of generating equipment is less than ten years old with all the attendant advantages of economy of operation and relative freedom from mechanical breakdown. This is in contrast to conditions just prior to our entry into World War II when only eight million kilowatts was less than ten years old and a relatively large proportion of the equipment then in service might have been classed as obsolete.

Continuing, Mr. Sutton pointed out that the present nine million kilowatts of reserve capacity provides a vast reservoir of surplus electric power which, if applied to two- and three-shift production, would make available an additional 100 billion kilowatt-hours a year. In other words, it would, under these conditions, increase by about a third the present annual output.

Thus it would appear from the standpoint of electric utility power supply that the country is in excellent shape to meet such demands as the present emergency may incur. Obviously, the figures cited apply to the country as a whole with conditions in some sections more favorable than in others for the strategic location of plants producing military supplies.

It is well to bear in mind that for a number of years past the total power supplied for public use, from all sources, has been predominantly steam, hydro having accounted on the average for only about 30 per cent. In fact, the T.V.A., which one usually associates with hydro power, is now engaged in building what will be two of the largest steam plants in the country. Since additional steam capacity can be made available in a very much shorter time than water-power developments, and at less initial cost per installed kilowatt, the several currently urged regional public hydro projects could have little or no effect in meeting the present situation. In fact, they would prove an obstacle by diverting manpower and materials that might be sorely needed elsewhere. This, of course, does not apply to additional hydro units in some existing developments where large blocks of power are essential to the production of certain bulk raw materials.

Still another important factor is that World War II experience is still fresh in the minds of power men, and many of those who played a major rôle in directing the power supply during that period are still available if a similar set-up again becomes necessary. This would obviate delay and confusion in getting started.

Therefore, viewing the power supply and probable demand from all angles, it is unlikely that military production in the United States would be seriously handicapped through lack of power, if the present situation becomes more critical. Very little information is available concerning power behind the Iron Curtain. It is axiomatic, however, that the key to success in modern warfare is the production line, where power supply is a predominant factor.

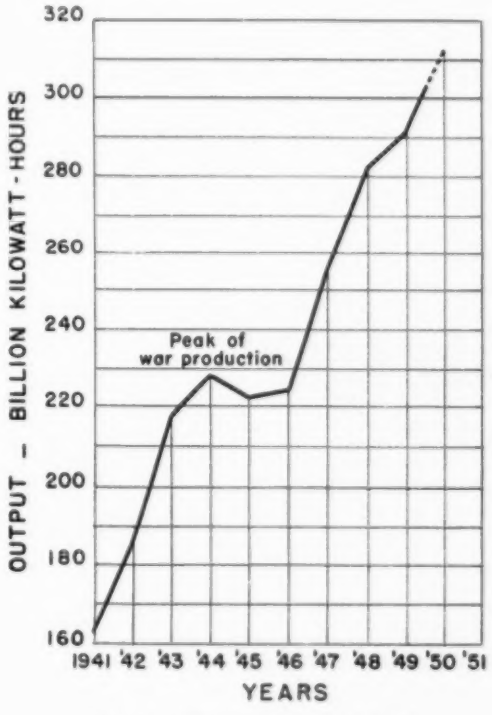


Fig. 1—Utility load, 1941–1950

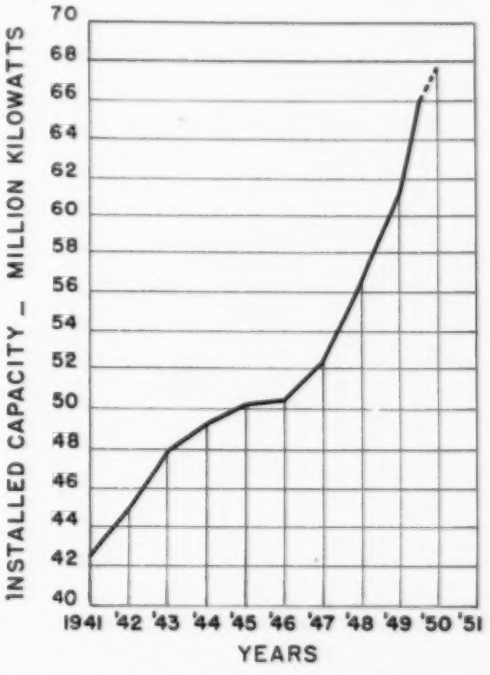


Fig. 2—Installed utility capacity, 1941–50

WORLD POWER CONFERENCE—II

Included in the second part of this report are abstracts and discussions of papers dealing with the production of power by steam engines and turbines, internal combustion engines, gas turbines and jet engines, hydraulic turbines, nuclear fission, wind, natural steam from the earth and thermal energy from the sea. Part I, which appeared in the August issue, dealt with papers on energy resources and power developments of countries participating in the conference and with the preparation of solid, liquid, gaseous and synthetic fuels.

Steam Station Design

A GROUP of papers presented by engineers from nine different countries dealt with Power Station Design. Some of these describe generating stations either existing or under construction in their respective countries, while others discuss problems relating to power station location and design. Most of the papers include references to problems encountered in using lower grades of fuel and in handling and disposing of fly ash; cooling water supplies and choice of steam conditions also are considered.

In a paper entitled "Problems Encountered in Connection with Recent Developments in Steam Power Plant" J. Gastpar of Sulzer Brothers, Switzerland, noted improvement in steam conditions as a prerequisite for obtaining greater economy and cited specific examples of installations up to 2133 psig and 968 F. He also emphasized the importance of developing fuel-burning equipment to enable the use of coals of inferior quality.

"Production of Power in the Union of South Africa" was the title of a paper by D. B. Reay, who enumerated the special conditions encountered in that country, where lack of cooling water and the isolated nature of industrialized regions have marked effect upon power plant design. Because of the low cost of coal and its advantageous location with respect to some of the industrialized areas, there has been a tendency to adopt conservative steam conditions, 600 psig and 850 F for units ranging from 30,000 to 45,000 kw being most common. Chain-grate stoker-fired boilers up to 200,000 lb of steam per hr are widely employed, though there are some large installations using pulverized coal. Scarcity of cooling water has necessitated the use of sewage effluent in at least two instances, while n other stations sea water, mine water and river water may be used, generally in conjunction with cooling towers. Except for pulverized-coal-fired stations, centralized control has not been generally adopted in South Africa, and the availability of native labor has been responsible for a lower degree of mechanization than is common practice elsewhere.

J. Ricard of the French National Committee discussed "Centralization of Power Production by Thermal Generating Stations." By means of probability computations applied to a large interconnected system, it is possible to show that, in a system consisting solely of steam plants, the "equivalent firm power" of newly added equipment is not very different from the "mathematical load expectation" of this equipment. He arrived at the conclusion that power plants, in regions of low load density, should be designed with a single unit; while those in regions of high density should have 100-mw groups.

"The Problem of Location of Large Steam Power Plants" was the title of a paper by W. Ney of the Polish National Committee. For conditions in that country conventional surface condensers are to be preferred to cooling towers at plants located at mine fields. To prevent air pollution by fly ash and sulfur dioxide, large power plants should be located in sparsely populated areas, and attention paid to prevailing wind conditions. Local requirements for a "security column" under power plant structures in mining districts dictate that power stations, if installed in such areas, be located on thin coal layers.

Difficulties due to a scarcity of native coal were analyzed by Ilidio M. Simoes in a paper entitled "Thermal Production of Electric Energy in Portugal." Although the scale of operation is small by comparison to other countries, the problem of securing the optimum balance between higher quality imported fuel, low-grade native anthracite and lignite, wood and certain vegetable waste products of low heating value is an interesting one.

"Power Stations in the Netherlands During the Last Ten Years" was the title of a paper by R. Kruk, who reviewed conditions which affected power plant operation during World War II. In post-war stations the practice has generally been to limit boilers to 300,000 lb of steam per hour, and to install two boilers for each 50,000–60,000-kw turbine-generator. Heat releases have been restricted to 16,800 Btu per cu ft per hr in order to obtain maximum availability. Steam conditions for new stations range from 850 to 1000 psig and 895 to 915 F, and to date reheating has not been adopted.

Boiler vs. Turbine Capacities

An interesting study of power station economics was presented by Emil Sóváry of the Hungarian National Committee under title of "A Method to Determine the Most Economic Relation Between Boiler and Turbine Capacities of Power Plants." Since satisfactory power-plant operation is dependent upon the simultaneous operation of every single element of the whole equipment, whatever piece of equipment has the smallest output capacity at a given instant affects the capacity of the entire power plant. If the capacity of the limiting equipment is increased, capital cost will increase along with plant capacity. An economic study must be made to determine the relation of the added plant output to the investment charges for the increased capital outlay. By analyzing the available annual operating capacities of individual pieces of power plant equipment and by com-

bining such an analysis with the economy study previously mentioned, the capacity of an item of equipment can be calculated. In this way the relative capacities of power plant equipment can be determined. The author derived suitable equations and developed an example relating to the economy of installing steam-piping interconnections for plants of basic unit design.

V. A. Pask, Chief Engineer of the British Electricity Authority, discussed "Modern Trends in the Design and Location of Electrical Generating Stations" in the light of two important external factors in Great Britain: the establishment of the grid system of central-station interconnection, and the effect of World War II upon power requirements. The British post-war power expansion is expected to total approximately 12,000,000 kw by 1955. Cooling water supplies are a troublesome problem, and in many inland stations not located on large rivers the use of sewage effluent water for cooling-tower makeup purposes is becoming common.

British Standardization

Because of increasing mine mechanization in Britain, ash content of coal is increasing, and ash disposal is becoming an important factor in station site selection. Standardization of plant design has become widespread as a result of overall national planning and the necessity of constructing additional generating capacity in the shortest possible time. Approximately 36 per cent of the post-war construction program is to operate at steam conditions of 900 psig, 900 F, using turbine-generators of either 30,000 or 60,000-kw capacity. Another standardized cycle has steam conditions of 600 psig, 850 F, using 30,000-kw machines. These two standard steam cycles account for about 81 per cent of the plant capacity now being installed. However, there are some stations projected for 1235 psig, 825 F using reheat and at 1500 psig, 1050 F with the straight-through cycle. Boilers up to a capacity of 265,000 lb per hr are mainly chain-grate or spreader-stoker fired. Those of larger size, making up 73 per cent of the total capacity, are pulverized-fuel fired, the maximum unit size now being designed being 830,000 lb per hr. With one exception, all of the pulverized-fuel-fired boilers are of dry-bottom construction.

American Practice

American central-station practice was the topic of a paper by P. W. Thompson of The Detroit Edison Company entitled "Operating Experience with High-Pressure, High-Temperature Steam Central Stations." Information upon which the paper was based was obtained, in part, through a survey conducted by the Committee on Power Generation of the Association of Edison Illuminating Companies. Improved dependability of the steam power plant has been achieved through close cooperation of manufacturers and users of power plant equipment in developing new designs, better equipment and advanced construction methods. In addition, refinements in manufacturing technique and improved operating and maintenance methods have contributed to greater reliability. Plant costs have been reduced because of the use of large capacity units, decreased requirements for duplicate equipment owing to increased reliability, and general simplification of plant structures. To some extent this has been counteracted by the added cost of more complex equipment necessary for operating at advanced steam pressures and temperatures. The latter, however, may be justified by their effect upon overall plant costs, including fuel costs and fixed charges. Annual availability of turbine-generators, excluding week-ends and holidays, averages 94 per cent, and some companies have extended operating periods to 40,000 to 50,000 hours between overhauls. A comparable availability figure for high-pressure, high-temperature steam generating units is 90 per cent, an important factor being that many governmental agencies and insurance companies require yearly inspection of steam generating equipment, as contrasted to turbine inspections which average three-year intervals. Another factor is that many plants have an excess of steam generating capacity, thus permitting more leeway in cleaning and in making normal repairs to equipment. With regard to water treatment, carryover from evaporators continues to be a serious problem, especially in connection with silica contamination of steam and its resultant deposition as an adherent, insoluble scale on turbine blades and in superheater tubes.

Practically all new capacity being installed or on order in the United States has rated steam conditions above 800 psig and 800 F, the highest operating temperature specified being 1050 F at pressures from 1500 psig to 2000 psig. There is a marked trend in new plant designs toward the reheat cycle to achieve further gains in thermal economy within the present temperature range, particularly for large-size units with anticipated high use factors. Outdoor and semi-outdoor plants are becoming more popular, and there is a trend toward generating units of larger capacity. Progress is being made in holding costs to a minimum through designs that reduce operating personnel and plant investment.

Steam Generation

There were eleven papers in the group dealing with Steam Generation. They indicated the extent to which advancing practice has come to the aid of fuel economy by enabling the burning of poor quality fuels at high efficiency. Notwithstanding these fuels, high availability has been maintained and unit size has been increased. Though the papers were representative of practice in eight different countries, they indicated general agreement on the direction which power plant practice will assume in the future.

"Developments in Water-Tube Boiler Design" was the title of a paper presented by W. F. Simonson of the Water-Tube Boilermakers' Association of Great Britain. Under the current construction program of the British Electricity Authority, 40 per cent of the boiler capacity is to operate at 925 to 975 psig, 900 F, and an additional 47.5 per cent, at 625 to 675 psig, 850 F; approximately 7 per cent is to have an operating pressure in excess of 1275 psig. As for firing, 67 per cent of the capacity will use pulverized coal and 27 per cent, traveling-grate stokers. To control boiler auxiliaries a unified system has been adopted. This utilizes variable-speed direct-current motors, the speed characteristics of which are correctly proportioned in relation to boiler output. By manipulating a single master control, the voltage of the d-c supply may be regulated, thus varying the speeds of individual auxiliaries. In looking toward the future, the

feeling was expressed that reheat would become more and more attractive, and that the combination of the gas turbine with the steam turbine appeared to offer important advantages.

There were two American papers on boiler design. "Design of Modern Steam-Generating Units for High-Pressure, High-Temperature Service" was the topic of a paper by W. H. Armacost of Combustion Engineering-Superheater, Inc., and "Trends in American Boiler Performance Requirements" was the title of one by W. H. Rowand of the Babcock & Wilcox Co.

Capital saving has influenced the trend toward large boilers of standardized design, as have the rising costs of fuel, construction and operating labor. By liberal furnace designs it is possible to burn wide ranges of fuels with annual availability in excess of 90 per cent. Steaming capacities have reached 1,370,000 lb per hr, while units have been constructed to generate steam at pressures up to 2300 psig, with a temperature of 1050 F and reheat to 1000 F. Superheat temperature control may be by means of tilting burners, desuperheaters, gas recirculation, or bypass dampers. Some designs use force draft only, while automatic boiler control is almost universal. The cyclone furnace is capable of burning low-grade coals, a large portion of the ash of which is collected as molten slag. Spreader stokers are frequently used up to 200,000 lb per hr and are adaptable to varying fuel quality. Methods of air heater washing include dry air, superheated steam, and alkaline solutions; acid cleaning is being used more and more to clean the internal surfaces of pressure parts. It is expected that, following suitable operating experience at steam temperature of 1000 to 1100 F, boilers will be designed for 1200 F at pressures of 2000 psig or more

R. S. deBeires discussed "The Production of Electric Energy from Portugese Anthracite of High Ash Content," using chain-grate stokers in boilers having a capacity of nearly 50,000 lb per hr. In the early design the fuel was burned by using a combination of a compartmented stoker and a mechanically driven, water-cooled agitator near the middle of the grate; also resort was had to the recirculation of fly ash. The later design employs a combination of overfire air directed against and across the travel of the stoker and concentrated high-pressure air under the stoker, and includes fly-ash recirculation. Dust from the discharged gases was reduced by the use of water sprays. A test efficiency of 63.5 per cent was attained.

Burning Low-Grade Coals

"Combustion of Low-Grade Fuels on Stokers" by J. P. Walters and H. A. Haines of the British National Committee dealt with the problem of the efficient utilization low-grade fuels on stokers specifically designed for better grades. Methods which have proved useful include (1) blending of good and poor grades of coal ahead of the stoker; (2) burning of washed slack on top of a layer of coke breeze; (3) conditioning of small coal with water or steam to obtain optimum moisture content; (4) an oil-assisted ignition system, in which oil is burned above the stoker and under the ignition arch; and (5) the steam-jet ignition system, which comprises a number of steam jet nozzles arranged in a horizontal plane and attached to a steam supply line. The latter is mounted on the lower end of the coal feed regulating shutter in such a manner that the steam jets retain their position to the fuel bed irrespective of its thickness. The last two methods thus far have been used only in smaller industrial plants.

C. S. N. Raju presented a paper on "Low-Grade Coals of India and Their Utilization for Thermal Power Generation" in which he pointed out the desirability of using the relatively plentiful supply of low-grade coal for power stations because of the limited reserves of high-grade fuel suitable for metallurgical uses. The cost of oil in India is such that it cannot generally be justified for power and steam generation, but a substitute liquid fuel might be alcohol manufactured from large quantities of molasses available from the sugar industry. The non-caking low-grade coals can be burned most efficiently in the pulverized state or on traveling stokers, and particularly on those of the spreader type. Two new steam plants, one of 80,000-kw capacity and the other of 200,000-kw capacity, are now being designed for the government of India to use these low-grade coals.

"The Use of Italian Fuels" was discussed by F. Roma and D. Sandulli, who noted that at present Italy is importing 85 per cent of her solid fuel requirements. However, there are extensive reserves of Sardinian coal, a typical analysis of which would be $7\frac{1}{2}$ per cent sulfur, 38 per cent volatile, 5 per cent moisture, and 20 per cent ash, with a fusion point of 2440 F. To burn this coal, chain-grate stokers may be used for units of up to about 135,000 lb of steam per hr, and above this capacity pulverizing may be employed, though large combustion chambers are required. Lignite fines, containing 45 per cent moisture, are also available and may be burned after pulverizing in hammer mills operating at around 400 F.

Marine Practice

In discussing "Oil-Fired Marine Boilers" W. Gregson of the British National Committee indicated that during the past decade marine propulsion has changed over almost completely to fuel oil. Boilers are of the header or multidrum type; and below 500 psig either an economizer or an air heater may be used, while above 500 psig both are generally employed. Typical steam conditions for post-war boilers in British vessels range from 250 psig saturated to 850 psig, 850 F with reheat to the same temperature. The most common conditions are in the range of 450 to 500 psig and 750 to 825 F. Some forced-circulation boilers of the Lamont type have been installed.

O. A. Wiberg and C. R. Nicolin of the Swedish National Committee in a paper entitled "Some Views on Combined Gas- and Steam-Turbine Plants" proposed that the upper temperature of the thermodynamic cycle be raised by employing a gas turbine in connection with a steam boiler and using the combustion air as the fluid in the gas turbine. The latter, in turn, would reject its exhaust heat to the boiler, thereby making possible a cycle efficiency as high as 45 per cent. Using a conventional boiler burning solid fuel, it would be possible to restrict the use of liquid fuel to the gas-turbine combustion chamber, thus requiring liquid fuel on the order of 30 per cent of the total. The proposed layout of the combined plant is relatively simple, since no heat-exchangers and no intercooling in the compressor would be needed. Maximum efficiency could be obtained at moderate gas-turbine pressures.

"Present Trends in Steam Generating Station Practice in Belgium" was the title of a paper by R. Beduwe and J. Bossaert. As Belgium has available practically no other primary energy source than coal, its power-producing equipment is composed principally of coal-burning plants. Low quality coals, including the by-products of grading and washing coals intended for other purposes, must be consumed, and these fuels impose certain conditions on furnace design and ash handling. These secondary coals amount to about 20 per cent of the total production, ranging from 6 to 30 per cent volatile, 20 to 45 per cent ash, and 3 to 30 per cent moisture. The largest standard turbine in use is a 50,000 kw unit, operating at 855 psig and 905 F with a single 450,000 lb-per-hr boiler. Pulverized coal has come into wide use in the larger plants, and restrictions on dust emission have required the installation of dust recovery equipment.

Steam Turbines and Auxiliaries

In the group of papers dealing with "Turbines and Auxiliaries," four were contributed by manufacturers and discussed present trends in the design of large steam turbines, one reported on the present position of the mercury turbine, another on the operation of cooling towers, another on the driving of steam-plant auxiliaries, and a final one on condensing steam by means of air.

"Design Trends in Steam Turbines of Large Output" was the title of a paper by F. Dollin of the British National Committee. There has been a great saving in weight and space as a result of improvements in mechanical design and construction materials which enable turbine operation at a speed equal to electrical frequency (3000 rpm). As an example, the 40,000-kw, 3000-rpm, two-cylinder tandem turbines at Earley power station have a specific output of 93 kw per sq ft of floor space and a specific weight of 7.5 lb per kw. To date 30,000 and 60,000-kw units have been standardized by the British Electricity Authority, and there is some prospect of standardizing 100,000-kw units in the near future.

Although new plants are intended to operate with a high load factor, they must also be suitable for intermittent operation. This may have a bearing on the steam conditions selected and on choice between two- and three-cylinder designs. Both impulse and reaction turbines are being built in large numbers. With the aerofoil blade profiles employed in 50 per cent reaction stages, substantially the same efficiency is obtainable with untwisted blades as with the twisted blades required by the vortex theory. In some impulse turbines, however, twisted blades are used throughout. With regard to the moisture problem it is pointed out that the net reduction in turbine efficiency resulting from the partial condensation of steam during expansion is much greater than the wetness loss factor as normally computed, and may be 6 per cent or more.

In the development of designs for operating at 1050 F, creep is a major factor requiring the introduction of new materials. It is suggested that forged molybdenum-vanadium steel or its equivalent be used for the steam chest and rotor, and that either forged or cast material of the same composition be used for the cylinder. For steam pipes it is debatable whether molybdenum-vanadium or austenitic steels are to be employed. For blading, austenitic steels of 18 per cent chromium, 8 per cent nickel, stabilized with titanium or columbium, are suitable.

C. B. Campbell of the Westinghouse Electric Corp., in a paper entitled "Trends and Development in Steam Turbine Practice for Central Station Service," reviewed progress over the past thirty years in turbine steam conditions and unit sizes in the United States. Standardization of large turbine-generators was initiated in 1938 and led to the "Preferred Standards" of 1945, as developed jointly by the AIEE and the ASME. Initially there were six ratings from 11,500 to 60,000 kw for 3600-rpm condensing units, the capability output being limited to 10 per cent above unit rating. Through 1946–1948 the experience of one manufacturer was that standard units accounted for 59 per cent numerically and 68 per cent by rating of the total turbines purchased within the scope of the Preferred Standards. Standardization has not impeded progress, for it has actually eased the demands on engineering design and has permitted the undertaking of more pioneer development than in any like period in steam turbine history. The majority of reheat turbines now on order are designed for 1450 psig, 1000 F, 1000 F. Two-casing tandem-compound reheat turbines are in manufacture for 100,000-kw maximum output, and triple-exhaust single-shaft designs will deliver 125,000 kw maximum at 3600 rpm. New rotor and blading alloys are undergoing investigation, and it is expected that these may be tested to the point where, in the near future, 1100-F turbines may be offered.

"Progress in Design of Steam Turbines for Electric Power Generation in the United States" was the title of a paper by E. E. Parker of the General Electric Company. The period during and following World War II was one which witnessed a large increase of generating capacity of which 80 per cent was steam. Although it might have been expected that design progress would have been sacrificed to attain increased production, such was not the case. Notable advances have been made in (1) the development of much larger units to run at 3600 rpm; (2) the manufacture of turbines for initial temperature as high as 1050 F; (3) improved designs and extensive production of turbines for 950 and 1000 F initial temperature; (4) widespread application of the reheat cycle under present-day conditions of temperature and pressure.

Improved Plant Heat Rates

Progress in engineering development has permitted continued reduction in the national average station heat rate and is resulting in the construction of new units with overall heat rates below 10,000 Btu per kwhr with an overall thermal efficiency approaching 37 per cent, based on the higher calorific fuel value. Where the power system is large enough to justify units with capacities of 100,000 kw or more, the single unit has proved to be more economical than two or more smaller units of the same total capacity. Improvements in construction and in the materials for turbine parts have been made to meet the requirements of higher temperatures and pressures.

"Mercury Cycle Power Generation—A Progress Report" was the title of a paper by H. N. Hackett of the General Electric Company. For a given initial temperature this is the most efficient electric power-generating cycle in commercial use today, and a 40,000-kw unit placed in service late in 1949 is expected to produce power at an overall thermal efficiency in excess of 37 per cent. Probably the most important development yet made in

mercury power generation was the discovery of suitable treatment of the boiler mercury, making possible the establishment of predictable and controllable wetting of the inside surfaces of the mercury furnace and the mercury boiler convection tubes. As long as the wetting action is maintained, the wetted surfaces are capable of absorbing heat at almost unbelievably high rates. At the same time, the metal wastage on the inside surfaces of the boiler tubes caused by the dissolving of the iron in the hot mercury may be substantially or entirely eliminated. The extensive use of the fog-type flow circuit has produced single-drum mercury boilers of a simple design, requiring a minimum quantity of liquid mercury. Standardization of mercury equipment, as a part of a standardized station, has been made possible because of the inherent thermal characteristics of the mercury itself. The relatively fixed ratio of mercury-turbine kilowatts to by-product steam produced has given the designer an opportunity to develop standardization to the fullest possible extent over a wide range of capacities.

A paper by F. Flatt of the Swiss National Committee on the subject, "The Driving of Auxiliaries in Steam Power Stations," describes how the part-load efficiency of high-pressure thermal plants of large output can be considerably improved by employing steam turbines whose overall efficiencies at low loads are not materially different from those at full loads. The boiler feed pump may be driven by a turbine which is supplied with extraction steam at a pressure sufficient to drive the pump with full load on the unit. At lower loads this extraction pressure may be lowered in a manner such that the drop in pressure matches very closely the drop in demand on the feed pump. The same steam turbine also drives an auxiliary generator which supplies the power required for other motor-driven pump auxiliaries, and the drop in speed of the feed pump turbine and its auxiliary generator enables the reduced demand on the auxiliary pumps to be met without generating full pressure and throttling the discharges of the various pumps. Similarly, it is proposed that the induced-draft fans be driven by a turbine in series with the main unit, taking the full quantity of steam. According to the variation of load and steam flow, the output of these fans may be matched with boiler requirements.

"Condensation by Means of Air for Steam Turbines Equipped with Injection Condensers" was the title of a paper by L. Heller of the Hungarian National Committee, in which he outlined a method by which it is expected that better operation can be obtained by using a jet condenser instead of the ordinary surface condenser. The cooling water used in the former is circulated in a closed cycle and is of the same quality as the condensate. At the base of the condenser some of the mixed condensate and injection water is withdrawn by an extraction pump and discharged to the boiler via the usual feed pump. The bulk of the water from the bottom of the condenser is then passed on the closed cycle to an external atmospheric cooler, where the water is cooled and supplied to the jet condenser under the turbine. Advantages of condensation by means of air instead of cooling towers are detailed by a series of calculations relating to proportioning the components of the system. It is claimed that, taking into account fixed charges and operating expenses, the proposed arrangement is more economical than the ordinary surface condenser using cooling towers.

A survey of the numerous factors affecting the performance of cooling towers was presented by J. C. T. Mulder of the Netherlands National Committee who based his study upon Merkel's 1925 mathematical analysis. This treatment of the heat and mass transfer process leads to the adoption of two dimensionless quantities which characterize the operating condition of a cooling tower. A functional relationship, known as the cooling characteristic, is found to exist between the two, and it is independent of temperature, humidity and water load. An important point of the analysis is that the driving force conveying the heat of the water to be cooled to the cooling air rising up the tower is the difference in the heat contained in each pound of air in the atmosphere before and after the air has passed through the water. In the paper several methods are given for calculating mechanical-draft and atmospheric towers having known characteristics.

C. Seippel of Brown Boveri, Switzerland, discussed "Some Thermodynamic Aspects of Power Production" primarily from the standpoint of the steam turbine. A steam turbine of 110,000-kw capacity, 3000 rpm was described from the point of view of proportioning the design to obtain optimum thermal efficiency. The author advocated that the ratio of the value of improvement, measured by a reduction in fuel consumption, to the cost of obtaining it should be the same for all portions of the turbine. No useful purpose is served by redesigning one particular section of the turbine at a certain cost when the same increased value might be obtained at a lower cost by improving the performance of some other portion of the turbine. The paper also includes the development of a theory of losses caused by rotational flow, a consideration of the merits of reheating, and a study of future possibilities of the steam turbine, gas turbine and both in combination.

Internal Combustion Engines

That section of the Conference dealing with internal combustion engines was made up of six papers, two each by the representatives of the national committees of Great Britain, France and the United States.

"Modern Trends in Oil Engine Design" was the title of a paper by I. Wans who discussed compression-ignition engines of the four-stroke cycle in sizes ranging from 5 to 300 bhp per cylinder and having crankshaft speeds of 1500 and 450 rpm, respectively. In present British practice with the higher-speed engines, the normal brake mean effective pressure, unsupercharged, is 80 to 90 psig, and the specific fuel consumption is 0.37 to 0.39 lb per bhp-hr. For medium-speed engines, comparable values are from 80 psig, unsupercharged, to 120 psig, supercharged with fuel consumption of about 0.375 lb per bhp-hr.

The second British paper, "Recent Developments in Lightweight Spark-Ignition and Compression-Ignition Engines, was presented by W. A. Robotham of Rolls-Royce, Ltd., who indicated that the compression-ignition engine is established as the most economical prime mover in the transport field. Specific fuel consumption of spark-ignition engines has been improved by higher fuel octane numbers and an increase in the highest useful compression ratio in the engines, one example being a series of six-cylinder gasoline engines of unchanged bore and stroke which have had an increase in output from 48

to 145 hp with less than 10 per cent increase in weight. Decreases in weight have resulted from the use of light alloys for cylinder-head and cylinder-block castings, and it is believed that a light-alloy passenger car engine can be produced weighing 30 lb per bhp, including all accessories, manifolds and flywheel. The author also mentioned the gas turbine but does not anticipate that this type of prime mover will displace any piston engines on a commercial scale in the field under discussion for the next five years.

"Comparative Efficiencies of the Main Types of Internal Combustion Engines" was the title of a paper by Max Serruys of the French National Committee. This report makes a detailed comparative study of the thermal efficiencies of the principal types of internal combustion engines and discusses recent attempts to improve these figures. A statement and appreciation of the values of thermal efficiency is followed by consideration of the possibilities of developing an indicator diagram more representative of practical engine efficiency. Two new forms of diagram are suggested, one for an ordinary reciprocating motor and another for such a motor in conjunction with a back-pressure turbine operated by the exhaust gases and possibly with a forced-feed compressor.

F. Picard, also of the French National Committee, discussed the performances, efficiencies and service characteristics of engines in relation to their overall economies in his paper entitled "On the Choice of Fuels for Internal Combustion Engines." Engine performance depends on specific weight, specific cylinder volume and specific fuel consumption. While the specific weights of gasoline engines decrease with cylinder size increase, those of oil engines increase; the lower maximum pressures of the former permit lighter moving parts, higher revolution speeds and lower specific weights. In choosing a fuel, three characteristics should be considered, namely, desired performance, transformation of energy (in which should be taken into account the best utilization of natural resources and the cost of operation), and the convenience of use, which may be very important to the operator.

With regard to American practice, R. L. Boyer of The Cooper-Bessemer Corp. presented a paper comprising a "Summary of Current Developments in Large Diesel and Gas Engines." The survey is limited to engines from 8 in. to 32 in. bore, with speeds of 1200 to 84 rpm, as used in stationary, locomotive and marine applications, including the dual-fuel type. In stationary practice in America, about 12,000,000 hp is now produced by gas engines, and an equal power by diesel engines. There are nearly 10,000 diesel locomotives, ranging in power from 600 to 8000 hp. Specific weights, in pounds per horsepower, range from under 20 for locomotive engines to 150 to 200 in slow-speed direct-driven marine engines. Specific consumptions of fuel oil of 0.36 lb per bhp-hr are common, while improvements to gas engines have reduced values to 6500 Btu per bhp-hr.

M. R. Bennett of the International Harvester Co. presented a "Summary of Current Developments in Small Diesel Engines" in which he confined his discussion to engines of below 8-in. bore. In the United States this type of engine has reached a stage of development where its structural and performance characteristics are comparable with those of carbureted engines in similar applications. The design is anything but standardized with respect to cycle type and combustion and injection system design. The recognized initial cost penalty associated with the diesel engine is offset by cycle efficiency and fuel cost economy, although both of these factors are susceptible to significant alteration upon the basis of future development in increased compression pressures in carbureted engines and reduced cost differences between gasoline and diesel fuel in the United States.

Gas Turbines and Jet Engines

The section on "Gas Turbines and Jet Engines" comprised seven papers covering a wide range of interests. The gas turbine is discussed in relation to power generation and aircraft propulsion; its use in land and marine propulsion is touched upon; its possibilities as an auxiliary to, or as a partner with, other forms of heat engine are discussed; and some of its potentialities as a component in industrial and chemical processes are indicated.

W. Karrer of the Oerlikon Company in Switzerland showed that a substantial economy in fuel consumption may be realized by combining the gas turbine with a back-pressure or condensing steam plant. Such a steam-gas system may be expected to have a thermal efficiency on the order of 40 per cent. Also discussed in this paper is the possible use of exhaust gases from high-temperature process, such as glass factories and cement kilns, as the heat supply to the gas turbine air. Somewhat analogously, gas-turbine exhaust gases might be utilized for supplying heating for low-temperature processes, such as drying or as preheated air supply for furnaces. The author provides a detailed characteristic example for each application.

"Some Technical Aspects and Applications of the Closed-Cycle Gas Turbine System" was the title of a paper by C. Keller of Escher Wyss Ltd., Switzerland. There is a basic similarity of steam turbine installations and gas-turbine installations operating on the closed cycle. Differences in construction details of components are mainly due to the different physical properties of steam and gas and the working pressures and temperatures in the two systems. With closed gas-turbine cycles a closer approach to the ideal Carnot cycle is also possible if individual efficiencies of compressors (87 to 90 per cent) and turbines (89 to 92 per cent) now attained can continue to be achieved.

The author described a closed-cycle gas turbine for use in connection with atomic power. Replacing a furnace would be a heat-producing pile which would transfer thermal energy to compressed helium in circulation. High-pressure helium leaving the pile could work directly in the closed-cycle driving the turbines, and being returned after recompression to the pile or circulated in a primary heating cycle. In the latter instance a tubular heat-exchanger might be employed to transfer heat to a normal closed-cycle air circuit. Since pressure could be kept high, the amount of heat-exchanger surface would be relatively small. For 1000-kw net output the amount of surface would be on the order of 850 to 1100 sq ft, and with small-diameter tubes the exchanger volume might be as small as 20 to 30 cu ft per 1000 kw. With small machines, even for large outputs, a totally enclosed combination of pressurized pile and machine set might be a further development. This sort of closed arrangement

minimizes the possibility of the escape of detrimental radioactive products.

British practice was reported by D. M. Smith of Metropolitan-Vickers Electrical Co. Ltd. in a paper entitled "Land-Type Gas Turbines." Although no land power gas turbines are yet in commercial service in Great Britain, several manufacturers have built and operated stationary gas turbines ranging in size from 500 hp to 2000 kw. Orders have already been placed for three gas turbines intended for central-station power generation. These comprise two compound open-cycle units having a rating of 15,000 kw each and a third of 12,500-kw capacity of the closed-cycle type with pressurized combustion, incorporating an open-cycle turbine in the combustion air circuit. All of these units will burn liquid fuel, but the future utilization of the gas turbine is largely dependent upon its ability to burn the cheaper grades of fuel, such as residual oil and coal. There are limited possibilities for gas turbines burning such gases as blast-furnace and sewage gas, and this type of prime mover deserves consideration for any new industrial plant yielding combustible gases as a by-product. Gas-steam cycles with coal-fired boilers pressurized by the gas-turbine plant offer a promising field for application of gas turbines to large-scale base-load generating plant.

"American Gas-Turbine Practice" was the title of a paper by L. N. Rowley and B. G. A. Skrotzki of *Power*, who analyzed the activities of eleven American manufacturers engaged in the design and development of gas turbines. The open cycle dominates gas-turbine practice in the United States, the only important exception lying in some work on the power-gas generator. Railroad locomotive applications appear to be one of the larger potential markets for gas turbines, and this has led to intensive developmental activity with a few basic designs. Experience in the aircraft industry has also been carried over to stationary power generation, and there have been a number of designs developed solely for stationary service. In competing with other types of well-established prime movers the gas turbine, though it may not operate with as high a fuel economy, has some special characteristics which provide a distinct advantage over other power devices. With the start of commercial operation both in stationary units and in railroad service, the most crucial phase of gas-turbine development in the United States has already begun. It is expected that the next few years will see increasing practical applications.

Maurice Roy of the French National Committee discussed "Methods of Power Production Involving the Use of Auxiliary Gas Turbines." Two systems which combine the use of gas turbines with alternative machines are considered: the "motor-turbine" system which is an internal combustion machine in which the driving turbine is mechanically independent of the motor-compressor unit, and the "equi-pressure" system introduced by M. E. Mercier. The first system is only suitable for medium-power industrial applications, such as rail traction and light ship propulsion. In the second, a free-piston compressor is employed in combination with an extremely compact boiler, and the combination is expected to have a thermal efficiency of the order of 40 per cent. The equi-pressure system is intended for application to large modern power stations.

The last two papers of this section were entitled "Power Plant Requirements for Future Aircraft," by F. M. Owner and S. G. Hooker of the British National Committee, and "Aircraft Gas Turbines" by J. S. Alford of the General Electric Company. The former paper attempts to analyze the separate factors affecting the main thermodynamic cycle and the propulsive mechanism. The authors consider that the gas-turbine power plant is made up of the power generator on one hand and the mechanism which converts the gas horsepower delivered into thrust horsepower driving the airplane. The turbo-prop, ducted fan, turbo-jet, ram-jet and piston engine are given attention, and comparisons of all these power plants are made on an overall efficiency basis and their respective fields of application delineated. Mr. Alford discusses general trends of recent aircraft gas-turbine developments in the United States. There have been increases in the unit capacity of turbo-jet engines and in thrust output and air consumption per sq ft of frontal area. Specific fuel consumption has been reduced by the use of cycle of higher pressure ratio, and there have been improvements in the efficiencies of the compressor, combustion system and turbines.

Design of Hydro Plants

There were twelve papers on the design of hydro stations. Ragnar Heggstad reported that five Norwegian power plants built into rock have been put into operation with a total capacity of about 340,000 kw. Experience to date has been satisfactory, and fifteen plants of similar design are now under construction and will come into operation in the 1950–1954 period. The twenty plants will have a total capacity of 1,600,000 kw, with individual capacities ranging from 4000 to 200,000 kw at heads running from 80 to 3300 ft.

E. B. Strowger, of Niagara Mohawk Power Corporation, indicated that in the United States increasing emphasis has been placed on functional design of power houses for hydroelectric development with many outdoor and semi-outdoor plants being built. Many new plants are being designed for non-attended operation, while older plants are gradually being converted to non-attended operation.

In Europe, according to M. Rousselier of the French National Committee, the size of hydroelectric schemes has been steadily on the increase for the last fifty years. Technical developments may allow for further increase in the size of such elements as tunnels, dams, pipe lines and power units, but in many cases the maximum economic sizes of these is found to be less than the maximum size technically possible.

M. Cabelka of the Czechoslovakian National Committee related the extent of losses in output and the increase in maintenance costs which have been experienced with low-head hydroelectric plants built next to weirs at the inner bank of bends in canals or rivers. From model experiments it was discovered that these losses, which are largely due to sedimentation, might be reduced if the weir is placed at the apex of a bend and the power station located on the outside bank of the bend.

In the United States, according to Messrs. W. F. Uhl, B. O. McCoy and W. P. Creager, the general trend in hydroelectric development is in the direction of simplification and improvement in construction methods. Multi-purpose river development programs have resulted in major projects with large generating units, and load conditions have given impetus to the creation of

head by means of dams instead of conduits. Better flow forecasting has enabled better flow utilization, and overall efficiencies have been improved to make greater power available.

Arne Fismen of the Norwegian National Committee described developments in the design, production and use of extra-high-head Francis (reaction) type hydraulic turbines. The reaction type, which has the superiority of inherently higher efficiency and provides the advantage of a larger-capacity, higher-speed alternator, has a present upper head limit of 1640 feet.

"The Replacement of Acceptance Tests on Site by Tests on Scale Models of Hydroelectric Power Plant" was the title of a paper by E. Seitz and C. Keller of Escher Wyss, Switzerland. They concluded that the accuracy and reliability of the results in model turbine tests and their applicability to the full-size unit have induced an ever-increasing number of users of large hydraulic turbines to recognize such acceptance tests as valid for the full-size units.

In his progress report on Italian hydro practice, Guido Ucelli emphasized the increasing prevalence of large-capacity machines and the tendency toward even larger ones. Noting that Italy has made significant advances in the design and production of hydraulic turbines, the author made a plea for international agreement to standardize specification requirements, particularly for performance guarantees and acceptance tests. He also expressed the hope that extensive contacts could be made with manufacturers of similar equipment in other countries, believing that such collaboration at the industrial and engineering level might be more useful in promoting international accord than would any political action.

J. Gastpar and R. Thomann of Sulzer Brothers, Switzerland, described a novel combination of pump and turbine for use in a pumped storage project having a 1575 ft head. Also mentioned were the use of special steels and the improvement of manufacturing methods which have permitted important savings in weight and required investment for high-pressure hydraulic pipe lines.

Hans Sorbye of the Norwegian National Committee described two types of separators for hydraulic conduits. One is based on the principle of creating an eddy in a belly at the bottom of an eccentrically widened part of the pipe line, and the other functions on the principle of creating an eddy in a transformed part of the tunnel just in advance of the forebay of the plant.

The last paper on hydroelectric installations was by R. M. Sedijatmo of the Indonesian National Committee and dealt with progress in the design of chamber surge tanks. Special attention is given to recent applications of double- and single-chamber surge tanks, and the author proposes a new type of single-chamber surge tank combining many of the advantages of earlier designs.

Power from Atomic Energy

Five papers on atomic energy were presented, representing viewpoints of engineers from five different countries. In those papers dealing with the economics of nuclear power, the forecasts made for future development were decidedly more conservative than some of the past speculations.

In a paper entitled "The Development of Power from Nuclear Energy," Sir John Cockcroft, Director of the British Atomic Energy Research Establishment, discussed the objectives of nuclear power research; three possible types of reactors; the probable line of development of nuclear power generators; reactors utilizing breeding, enriched thermal fission and natural uranium thermal fission; the technical problems of nuclear reactors; and the time scale of the development of nuclear power. The transfer of heat from a nuclear reactor to a conventional power-generating system is likely to be the first form of the development of nuclear power, and for this purpose experimental prototype reactors are being designed and built. In the course of development the following are the principal technical problems that must be faced and solved: high-temperature operation, high heat transfer rates, neutron economy and breeding, long operating life, development of economic chemical processing methods, and disposal of radioactive waste. It is expected that the building of experimental reactors will require the next three to five years and that the ensuing five years will be necessary for gaining operating experience and designing full-scale nuclear power producers. Extensive development of nuclear power on a large scale may have to wait until the decade following the period of operating experience.

L. Kowarski, Scientific Director of the Atomic Energy Commission of France, reported on developments in that country, noting that the annual expenditure for that purpose is 0.2 per cent of the total national budget. A small nuclear reactor is already in operation, and a second pile of about 1000-kw capacity is now being erected. Success has been achieved in the training of scientific and technical specialists in nucleonics. However, effective realization of power production still must be placed remotedly in the future.

According to a paper by W. F. Davidson of Consolidated Edison Co. of New York, the technical problems that must be solved before nuclear reactors for the generation of power can be successfully built have proved more difficult than was anticipated three years ago. To date adequate facilities are not available for developing materials with low specific neutron absorption, stability when exposed to intense neutron radiation, and suitable physical properties at elevated temperatures. It appears that non-fissionable uranium 238 and possibly thorium 232 may have to be used instead of fissionable uranium 235 or plutonium 239 in designing breeder reactors for large-scale power production. Even with the solution of technical problems, it is not expected that the cost of nuclear power can be much below that of coal burning and hydroelectric plants, unless operation is on a multipurpose basis in which a large part of the costs is allocated to other operations. Safety considerations and disposal of radioactive wastes add considerably to the general costs.

David A. Keys, vice president of the National Research Council of Canada, reported on the Chalk River project, where there are two heavy-water reactors in operation. The larger of the two is specially designed for research with particular devices for irradiating materials for the production of radio-isotopes and for providing beams of neutrons for experimental purposes. Owing to the high neutron flux density, facilities are available for investigating and producing isotopes of high specific activity. The Canadian effort is directed toward the peacetime and educational aspects of atomic energy and

includes cooperative projects at a number of universities throughout Canada.

"Some Economic and Technical Aspects of the Use of Nuclear Fuel for Power Production" was the title of a paper by Ragnar Liljeblad of the Swedish National Committee. A uranium pile with an electric output of 100,000 kw and 25 per cent overall efficiency would require about 100 tons of uranium. With it a suitable cooling liquid, such as molten bismuth, would have to be used. If gas were to be used as the cooling medium, probably not more than one-tenth of the heat could be used and the size of the pile would become prohibitive.

Power from the Wind, Natural Steam and the Sea

"Recent Developments in Large-Scale Wind Power Generation in Great Britain" was the title of a paper by T. G. N. Haldane and E. W. Golding, who gave a brief historical review and gave reasons for considering wind power as a means of generating electricity on a large scale. It is assumed that a commercial generator driven by this means will start to deliver power to a synchronous alternating-current system when the wind speed reaches 15 mph and will be disconnected at velocities in excess of 70 mph. A 100-kw aero-generator is scheduled to go into operation this year, and if experiments prove successful, consideration will be given to the design of a machine of 1000 to 2000-kw capacity.

Enea Virgili of the Italian National Committee reported on "The Application of Natural Steam to the Production of Electric Power." In the Larderello district of Italy is located the most important application of geothermic heat in existence, and since 1949 power produced has been more than one billion kilowatt-hour per annum. The steam obtained is wet saturated, with a temperature range from 285 to 420 F, a pressure of 15 to 18 atmospheres (220 to 265 psig), and a dryness fraction of 0.8 to 0.9. It is mixed with other gases, including carbon dioxide, hydrogen sulfide, hydrogen, methane and nitrogen. The steam may be used in three ways: (1) in a back-pressure turbine, coupled to an alternator and exhausting into a chemical plant; (2) in condensing turbines, in which the steam required is supplied from heat-exchangers; and (3) in condensing turbines supplied directly with the steam-gas mixture and evacuated by means of turbo-exhausters. The second and third methods cost about three times as much as stations operating with back-pressure turbines, but the steam consumption is only about three-quarters as much with condensing turbines operating in conjunction with heat-exchangers and half as much with condensing turbines supplied with the steam-gas mixture.

"Industrial Utilization of the Differences of Temperature Between the Deep and Surface Waters of the Sea" was the title of a paper by C. Beau and M. Nizery of the French National Committee. In tropical seas the vertical temperature gradient exceeds 68 deg F between the surface and a depth of 1640 ft. The thermodynamic cycle consists in evaporating under vacuum part of the warm surface waters. The steam is "inhaled" by the condenser, which is cooled by the deep waters. Enroute to the condenser the steam passes through a turbine which drives an electric generator. The weight of materials per 1000-kw produced is as follows: cement, 68 lb; steel, 350 lb; non-ferrous metals, 0.44 lb; rubber, 3.5 lb. The project at Abidjan on the Ivory Coast (Africa) is expected to consist of two generating sets, each of 3500-kw capacity.

Discussion[1]

A member from France pointed out that they are faced with serious problems due to coal of 50 per cent ash content. Consideration is being given to the transportation of mine washings consisting of a mixture of three parts water and one part coal over considerable distances to power plants. The water used for transporting the coal would then be removed and the quantity fits the water requirements of the plant.

A member from Great Britain stressed the desirability of locating small stations near the load to save transmission loss, and pointed out that studies have indicated the cost of transporting coal 450 miles by sea to be no greater than transporting it 30 miles by rail. He also stated that the peak rate of the poorest 25 per cent of Great Britain's power stations is twice that of the best 25 per cent; therefore one per cent loss in availability of best stations means one per cent loss in station efficiency.

Dr. Munzinger (Germany) presented a comparison between the Rankine, Field, and closed gas-turbine cycles, on the basis of 1200 F working medium, and 100,000 kw units. The relative efficiencies given were, respectively, 39.1, 38.8 and 36.0. He therefore predicted that the predominance of the Rankine cycle would continue for at least ten years with coal firing. In his opinion radiant superheaters will be necessary in order to go to higher steam temperature than present practice. He recommended use of "channel" type superheaters in which the tubes are heated over the entire circumference. He indicated that Benson boilers have serious troubles under certain operating conditions and that the La Mont type may find wide application for high-pressure units.

Another member from Germany pointed out that the trend there is toward the largest possible units for the larger power systems, but that the use of brown coal restricts the plant design. Turbine units for up to 100,000 kw are developed.

Mr. Woodcroft (Great Britain) mentioned that a turbine outage for overhaul of eight weeks every two years must be considered necessary and six weeks per year for boiler overhaul, in addition to cleaning periods every six months.

Mr. Shannon (Great Britain) stated that they do not expect any trouble from graphitization due to the fact that they do not use aluminum for de-oxidation of steel. Moreover, steel containing 0.5 per cent Mo and 0.33 per cent Va has been used for 965 F. He warned that further investigation in the use of austenitic steels for high-temperature use will be necessary because of the sigma phase which occurs at temperatures over 1200 F.

Mr. Wiberg of Sweden pointed out that much experience had been obtained in his country with Ljungstrom radial-flow turbines on quick start-ups, and a 65,000-kw unit had been started from cold to full load in eight minutes. He believed that the same results could be accomplished with this type of turbine on 100,000 kw capacity.

[1] Reported for COMBUSTION by W. S. Patterson.

Mr. Field (Great Britain) inferred that temperatures above 1050 F should be considered with caution because of the necessity of using austenitic steel. He proposed a station cycle combining gas turbine and steam capable of over 40 per cent net station efficiency.[2]

Dr. Levi (Israel) reviewed troubles experienced with oil firing and mentioned damage to the economizer from external corrosion by acid resulting in need for economizer replacement every three years.

Much of the discussion by members from Great Britain was in connection with quality of coal and methods of preparing coal for stoker use. One member pointed out that certain alkalies in the coal ash are responsible for formation of slag independently of fusion temperature and they are also responsible for economizer and air-heater deposits. He felt that constituents such as sodium, potassium and lithium are also responsible for external corrosion in slag-tap units which has been reported in the United States.

Mr. Reece (Great Britain) called attention to a recent threat to availability due to internal deposits containing a high copper content. The onset of such trouble is sometimes very sudden and he inferred that it might be necessary to limit the maximum rate of evaporation per square foot of boiler surface to prevent such trouble.

In closure, Mr. Campbell stated that they generally choose austenitic steel for contact with steam at 1050 F or above.

Mr. Dollin recommended that every effort should be made to avoid the use of this steel in turbines Mr. Parker stated that further development of ferritic steels has been carried out and that two turbines for 1050 F are being built by his Company using ferritic steels.

Dr. Seippel stated that the use of reheat is much less attractive on 50-cycle systems than on 60-cycle systems.

Criticism of the paper on nuclear energy for power production by W. F. Davidson was made by the leader of the Russian delegation. He indicated that the Soviet representatives felt that the assertions were misleading and they directed scientists in their researches along the wrong road, particularly with respect to finding peaceful uses of atomic energy as a by-product of military activities. A spirited defense of Mr. Davidson was made by Ernest Mercier of France, who stated that the interpretation of the former's statements by the Russian delegate was unwarranted.

[2] Described in COMBUSTION, April 1950.

Facts and Figures

The largest steam turbine-generators now on order are of 160,000 kw.

•

In Finland approximately 70 per cent of the industrial fuel is made up of logs and wood refuse.

•

In general, a gas temperature of 1000 F or higher will justify use of a waste-heat boiler.

•

In the last 15 years the number of heat-pump installations in this country has increased from two to approximately 500.

•

The mesh of a screen, such as used for measuring the fineness of pulverized coal, is designated by the number of openings per linear inch.

•

Sales of electricity to ultimate consumers are divided as follows: industrial, 48.2 per cent; residential, 26.2 per cent; commercial, 17.6 per cent; others, 8 per cent.

•

Direct-fired mills are usually capable of handling up to around 600-F air without tempering, whereas the outlet temperature will range from 150 to 180 F.

•

Carryover and priming are sometimes confused. The former applies to contamination of the steam by boiler water or boiler water salts, and is usually caused by foam on the surface of the water; whereas priming is a violent carryover of water with the steam and is essentially mechanical.

•

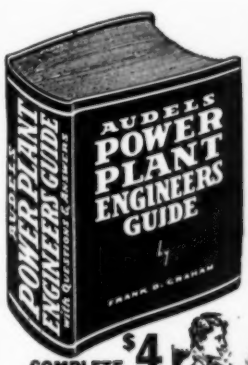
It is estimated by Appalachian Coals Inc. that the 1950 usage of bituminous coal will approximate 461 million tons and that the production will reach 500 million tons, the difference being that added to storage.

•

Exports of crude oil, residuals and other petroleum products are now about the same as they were in 1940, although imports have increased $2^1/_2$ times during the last ten years. Despite this, they represent only about 15 per cent of the domestic production.

•

Studies of dust deposition from stacks, as made by the Atmospheric Pollution Committee in England, reveal deposits of about 1000 tons per square mile per annum in highly industrialized areas, 100 tons under reasonably clean urban conditions, and 10 tons in country places.



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Damage to Superheaters and Air Preheaters with Oil Firing*

Under certain conditions boilers in the power station at Västeärs, Sweden, have suffered severe damage when fired with oil fuel. This damage, which was confined mainly to the two largest units, has appeared in two distinct forms, namely, corrosion on the flue gas side of the superheaters and the air preheaters, also fire in the latter.

By H. LIANDER,
Chief Engineer at A.S.E.A.

THE nature and the causes of the corrosion commonly experienced in air preheaters of the regenerative type are generally known and will only be referred to briefly. In order to obtain optimum boiler efficiency by extracting the maximum amount of heat from the flue gas, it is common practice to approach as close to the dew-point as possible without risking condensation. A high sulfur content in the fuel entails a considerable risk of formation of sulfuric acid, especially if there is a catalyst present to promote the oxidation of sulfur dioxide to trioxide. As an example, may be mentioned vanadium oxide, traces of which are often present in mineral oils. However, iron is also an effective catalyst, especially in the form of sulfate. Should the temperature fall below the dew-point, even for a brief period, water containing sulfur dioxide will condense on the plates in the preheater and attack them, forming iron sulfate, which will then facilitate continued corrosion even at a flue gas temperature considerably above the theoretical dew-point.

Fig. 1, depicting the Ljungström preheater of one of these large units, shows how this kind of corrosion may, at least to begin with, be restricted mainly to a single section, that has evidently been subjected to condensation at one time or another. The iron sulfate which has resulted, and is clearly visible as a white deposit along the upper edge of the sheets, has acted as a catalyst in the formation of sulfuric acid from the flue gas. Owing to this catalytic action the corrosion continues long after the temperature of the flue gas has attained values which under normal conditions would not be detrimental.

Provided it is not allowed to progress unchecked, such damage is not likely to jeopardize service. Nevertheless, renewal of damaged sheets entails a considerable work and expense, and it is therefore advisable to employ non-corroding material for the sections exposed to the severest attack and to exercise effective control of the dew-point.

Corrosion of a more unusual kind has occurred at the superheater tubes of this unit and in one of the preheaters of the other unit.

When firing certain grades of oil—in this case, a heavy Persian oil—signs of corrosion were observed in the above mentioned places after a few weeks running. On the superheater tubes it appeared in the form of a dense, adhesive coating of corrosion products, which varied in thickness from one to several tenths of a millimeter. So far, the damage is not sufficiently advanced to be considered serious, but the safety of the superheater may be imperiled if it is allowed to remain in service under the same running conditions.

The damage suffered by the air preheater was of a far more serious nature. This preheater is built up of vertical ducts, the sides of which are made of austenitic nickel-chromium steel and contains corrugated sheets of 17-per cent chromium steel. The hot flue gases pass through the channels formed by the corrugated steel and the sides of the ducts. Air enters at right angle to the flow of flue gas, on the inside of the ducts, which contain horizontally corrugated 13-per cent chromium steel. The corrugated heat-resistant sheet (Fig. 2) showed evidence of severe attack by the flue gas on both sides. Products of corrosion were found in clearly discernible layers, and at the lower edge, where the gas enters, the metal was completely consumed. A white deposit covered an extensive area, and wartlike blisters that appeared on most parts of the affected surface were, on closer examination, found to be hollow and contain a white powder under the dark-colored outer skin.

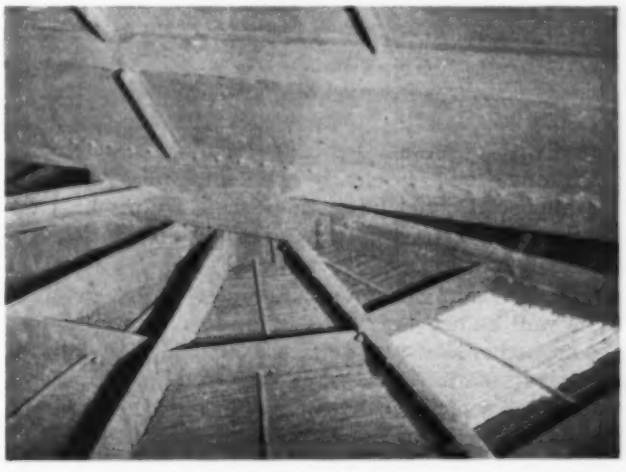

Fig. 1—Sector of air preheater, showing effect of corrosion caused by sulfuric acid contained in the flue gas

Even the austenitic sheet, which encases the air channels, was badly damaged. At the lower edge the 1-mm thick steel was entirely corroded away. There was no evidence of corrosion inside the air passages, and the corrugated chromium steel filling which is exposed to the

* Translated from *Teknisk Tidskrift*

scouring action of the air was in the same condition. The possibility of oxidation due to excessive temperature was therefore excluded, as otherwise the corrosion on the side exposed to the incoming air should have been more severe owing to the higher partial pressure of oxygen.

A closer investigation revealed, however, that the damage was entirely due to oxidation. Samples cut from the plate clearly revealed the characteristic layers of corrosion products, with ferrous oxide nearest the metal and a succession of higher oxides toward the surface. Analysis

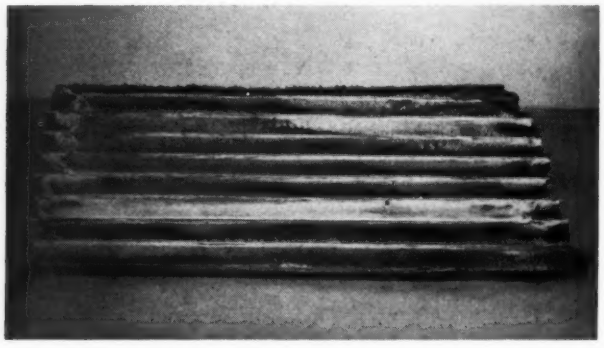

Fig. 2—Preheater plate damaged by alkaline corrosion

of samples of the oxidized scale covering the chromium alloyed plate showed it to contain oxides of iron, chromium and nickel in approximately the same proportion as the constituents of the plate metal. The analysis also showed sulfur to be present in varying quantities.

As nickel is a constituent in both of the metals which had suffered corrosion, there might be reason for suspecting that the sulfur present in the flue gas was alone responsible for the damage. However, this possibility is excluded by the very nature of the oxides. A metallographical examination failed to reveal any penetration of sulfides in the grain boundaries, such as is commonly associated with nickel-alloyed heat-resistant steels exposed to sulfurous gases. A clearly defined boundary between oxide and steel could be distinguished, from which the inference may be drawn that uniformly distributed corrosion had affected extensive areas. Fig. 3 shows the plate section magnified about 500 times.

It is well known that the immunity of chromium-alloyed and other heat-resistant steels to oxidation depends upon the formation of a comparatively thin film of oxides through which hardly any diffusion of oxygen can reach the metal, nor metal travel toward the surrounding atmosphere. The cause of the corrosion is therefore to be sought in a breakdown of this protective oxide film, and the next step in the investigation was to establish the manner in which this had occurred.

Analysis of the white deposit on the metal plate proved it to consist mainly of sulfate of the alkali metals (81 per cent if calculated on Na_2SO_4) together with small quantities of calcium, manganese and vanadium salts, and an insoluble remainder of 9 per cent. The white powder contained in the blisters was of similar composition, whereas the enclosing skin was formed of chromium and iron oxides. The alkali sulfate undoubtedly originated from the fuel oil. The figure for the sulfur content, 1.9 per cent, is not abnormal for the type of oil used, whereas the ash content, 0.06 per cent, must be regarded as high.

The probable manner in which the corrosion occurred is therefore as follows: Alkali sulfate is formed in the combustion of the oil and is deposited on superheater and preheater surfaces. Excess sulfur turns at least some of the sulfate into pyrosulfate, which successively attacks and penetrates the protective oxide layer as it forms anew. In this way the oxidation process is able to continue until the metal is consumed.

The possibility of finding a material suitable for use in superheaters and preheaters which would be immune to attack under the prevailing boiler conditions was regarded as remote, and under the circumstances the only effective method to be recommended is to change over to some other fuel.

With reference to the fire in the preheater, the unit had been taken out of service in the normal manner in the late evening and the rotors of the two Ljungström preheaters allowed to run in order to cool down, with only the natural draft through the boiler. When the work of soot blowing commenced a few hours later, the fans were started up again and shortly thereafter the motor driving one of the preheater rotors was tripped, bringing the rotor to a standstill. Attempts at restarting it were unsuccessful, and upon inspecting the preheater, the top cover plates were found to be red-hot. The fans were immediately stopped, but by this time the fire had gained a secure hold, the whole boiler reverberating with the crashing of molten steel as it ran down on to the economizer below.

An attempt was made immediately to lower the steam pressure by tapping off boiler water and injecting feedwater for the purpose of cooling the economizer. In order to prevent the fire from spreading all dampers and apertures were closed, despite which sufficient air found

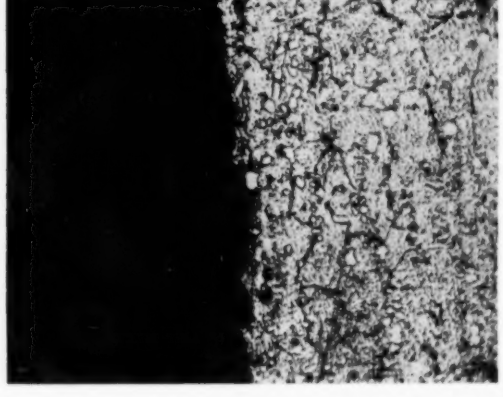

Fig. 3—Chrome-alloyed plate, magnified 400 times

its way in to keep the fire alive. Finally, the fire brigade was summoned, and by using foam extinguishers and spraying the boiler with water succeeded in preventing the fire from spreading to the oil contained in the gear box, and the molten steel from breaking through the cover plates and air drum. The conflagration was gradually brought under control, and toward morning all danger to the plant was considered over.

Meanwhile, the other preheater had at first been kept turning, but was stopped after a few hours as it was thought to be in danger of seizing.

Fig. 4—Damage caused by fire in air preheater

While it had thus been possible to avoid a major catastrophe, the damage to the preheater was nevertheless extensive. Fig. 4 shows how the sheet steel gave way and partly disappeared into the rotor. The latter is built up of two layers, the upper consisting of ordinary 0.5-mm thick mild steel and the lower being heat-resistant steel of the same thickness. Only the upper sheets were burned, the fire apparently having commenced in the joint between the mild steel and the heat-resistant sheets. Molten steel ran down between the heat-resistant sheets, as shown in Fig. 5, and caused some damage to them. Also, considerable quantities of steel and slag were found adhering to the sides and, as shown in Fig. 6, can be seen some of the metal which fell on to the economizer tubes. The girders supporting the air preheater were distorted by the intense heat, although the motor and gearbox of the unit were practically undamaged by the fire.

A bituminous deposit found on the plates of the undamaged preheater, as well as on the less damaged plates of the burnt one, was evidently due to the fuel oil. Previously, a lighter fuel oil had been burned and the later change-over to heavy oil was made before oil heaters could be installed. This resulted in incomplete combustion of the heavy oil; and drops of unburnt oil, from which the lighter fractions had been driven off, had been carried along by the flue gas and deposited in the preheater.

A review of the cause of the fire led to the following conclusions:

As the fans were stopped when the unit was taken out of service, the natural draft through the boiler caused a stream of hot air to flow through the preheater. The latter no longer being cooled, the temperature slowly rose to the point at which the oil deposit ignited. The fans were then started up again, nourishing the fire, which grew so hot that the sheet steel melted.

Another contributing factor was oxidation of the steel. This oxidation was accompanied by evolution of considerable heat, depending upon the stage of oxidation reached. But the resulting coat of iron oxide tended to prevent further reaction, and when it reached a certain thickness, the rate at which oxidation continued depended mainly upon how rapidly the oxygen was able to diffuse through to the iron, and the iron out to the surrounding atmosphere. At elevated temperatures the diffusion rates may be so high that the heat evolved in the reaction cannot be carried away, with the result that the temperature rises rapidly to the melting point of both steel and oxides.

Fig. 6—Quantities of molten steel dropped onto the economizer

Once heaters for the fuel oil had been installed it was thought that all risk of fire in the air preheaters was over. Despite this, another fire broke out shortly afterwards in the other preheater, although it had been carefully cleaned subsequent to the first outbreak. Whether the second fire was caused by oil deposits that had been overlooked, or by a fresh deposit, was impossible to determine.

Apart from the removal of heat by the air flow, other important factors which reduce the risk of fire are the heat capacity of the metal sheet and its protection against radiant heat. Fine-gage sheet and a small clearance between the sheets will enhance the risk, a fact that is borne out by experience. It is possible that on the second occasion the metal sheet may have been more susceptible because of the reduction in thickness brought about by the corrosive action of sulfuric acid condensation.

A simple laboratory test, aimed at simulating the conditions which led to the fire, is illustrated in Fig. 7.

Fig. 5—Iron and iron oxides that melted and flowed through part of air preheater

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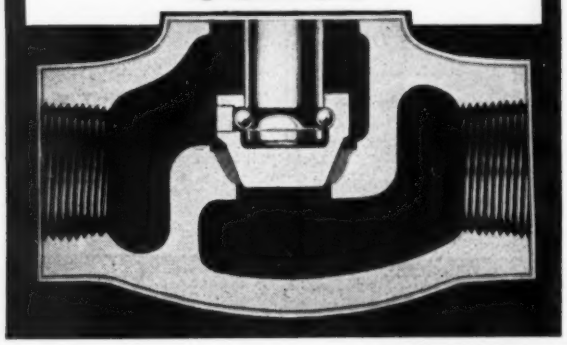

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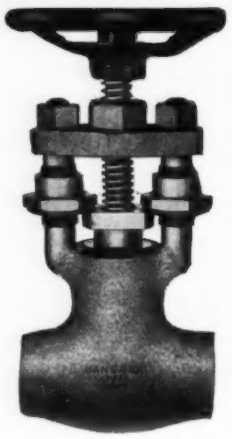

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Strips of sheet steel were placed vertically on a layer of coarse fire clay in a vertical refractory tube which was heated electrically. With a slow convection current rising through the tube, the temperature was raised at the rate of 200 deg C (392 deg F) per hour. The temperature was measured by means of "chromel-alumel" thermocouples placed below and inside the bundle of strips.

Conditions of Test

The test was first carried out with steel strips obtained from the preheater which escaped damage in the first fire, but which were coated with the oil residue. Ignition took place at 800 C, and thereafter the temperature rose rapidly above that of the surrounding atmosphere. In practice the ignition temperature was probably still lower, as the oil residue had doubtless suffered distillation and partial carbonization.

The second tests concerned the same kind of strip, but devoid of any oil residue. The object of the test was to ascertain at what temperature the oxidation proceeded so rapidly that the metal commenced to "burn." Unfortunately, the test apparatus was not capable of producing temperatures above 1065 C, at which value no spontaneous ignition had taken place. It was therefore not considered worth while to repeat the test with the heat-resistant steel.

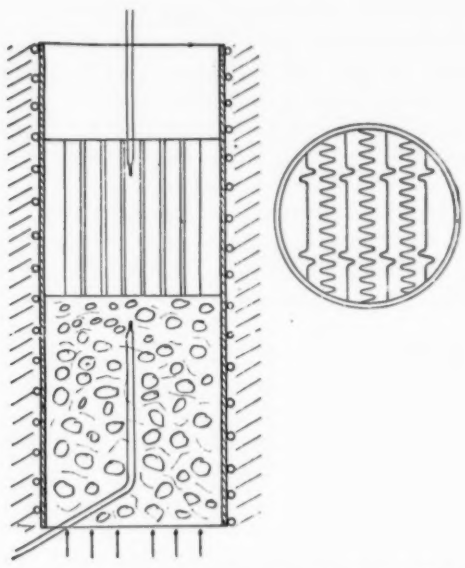

Fig. 7—Test rig for investigating properties of plate showing location of thermocouples

Experiments conducted on a more extensive scale, using apparatus capable of a more comprehensive range of testing, are desirable. The recommended procedure would be to subject bundles of strips of carbon-steel and heat-resistant alloys of various gages and spacing to predetermined temperatures in a furnace, in an atmosphere of nitrogen having a certain flow rate. When a condition of thermal equilibrium has been reached, an air stream flowing at the same rate should be substituted for the nitrogen, and any subsequent rise in temperature should be noted. This test should be carried out at various flow rates and temperatures.

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By G. V. WILLIAMSON
Union Electric Co. of Missouri

IN 1920, the typical large single-shaft turbine had a capacity of 20,000 kw and was served by perhaps five boilers, including one spare. With single turbine sizes increasing to around 80,000 kw by 1940, or four times the 1920 turbine, two boilers were, in general, required to meet its steam demand; or, in terms of electric output, boilers of 40,000 kw each.

Both the operator and power plant designer realize that there are many advantages in having a single boiler for each turbine, providing the boiler dependability equals that of the turbine. Turbine availability had long been in excess of 95 per cent and in some cases as high as 98 per cent, whereas most boiler availability had previously been of the order of 85 to 87 per cent. But improvements in design have brought the availability of modern steam generating units very close to that of the turbine, so that it is now possible, without much risk, to employ a single boiler to serve the largest desired turbine. Thus we now find a 125,000-kw turbine-generator, which is six times that of the 1920 unit, matching a single 125,000-kw in boiler capacity, which is sixty times that of the 1920 size. In short, in thirty years while turbine size has been growing sixfold, the boiler has grown sixtyfold, and boiler size has been increasing ten times as fast as turbine size.

The rapid increase in size of boiler has been impelled by the desire to simplify plant design so that one boiler, one set of piping, one set of auxiliaries, and one set of controls serve the entire unit. Such simplification has, of course, led to lower first costs, more dependable operation, better adaptation to instrument control, and lower operating and maintenance costs, all at only a slight decrease in plant availability.

We of the Union Electric organization in St. Louis have reviewed in considerable detail developments in the design of steam generating units which have permitted such tremendous growth. These have been reduced to 24 points which we believe should be included in a modern unit. They can be divided between those that have already been achieved and those which have in part been accomplished or give promise of being attained. They are points which a prospective purchaser might want to review in making his selection. Needless to say, the technical developments which these points cover reflect great credit to the designer and manufacturer of such equipment.

Twenty-four Points of Good Design

A. Twelve points already in large part achieved
1. Adequate water circulation in all tubes of boiler, economizer, and furnace water walls.
2. Problems of water, including caustic embrittlement, heavy scale, and corrosion; reasonable blowdown.
3. Design of boiler parts for good heat absorption, for high pressures of 1000 to 2000 psi, and design of superheater for 900 to 1100 F.
4. Elimination of tube replacement problems by welding repair methods.
5. Design of boiler surface to accommodate high feedwater temperatures of 350 to 500 F.
6. Furnace bare-tube water-walls, solid banks of tangent tubes with minimum refractory protection.
7. Adequate soot-blower cleaning of furnace walls and boiler sections with steam or air, and long soot blower life.
8. Generally satisfactory air heaters.
9. Large, high-capacity boilers—over million pounds of steam per hour.
10. Coal pulverization over wide range.
11. Quick and sustained ignition.
12. High efficiency, smokeless combustion.

B. Twelve points partly accomplished or in process of attainment
1. Provision of sufficient furnace water-wall surface to avoid slag, compatible with cost and fuel ignition.
2. Superheat and resuperheat control for adequate load range.
3. Elimination of boiler passes and hoppers; low draft loss.
4. Low gas velocities through boiler tubes.
5. Good steam scrubbers, low carryover, only one boiler water drum.
6. Low flue gas exit temperatures—280 F and below.
7. Pressurized furnace—elimination of induced-draft fans.
8. Designs suitable for outdoor installation.
9. Control of fly ash.
10. Range of steaming capacity—20 per cent to overload.
11. Suitability to remote and centralized control.
12. High availability—few short outages for inspection and repair.

Points Already Attained

The vast increase in capacity has been brought about largely by making the heat-absorbing surfaces work much harder than in the boiler of thirty years ago. In those days 100 to 150 per cent of boiler rating was generally considered satisfactory. This was gradually increased in the late Thirties to perhaps 500 per cent of rating, which meant that each square foot of heating surface, instead of producing three pounds of steam, corresponding to 100 per cent of rating, was perhaps producing 15 lb of steam. So great, however, has been the later improvement in circulation of the water in the boiler tubes, economizer, and particularly in the furnace wall tubes, that now heat absorption rates in excess of 100,000 Btu per sq ft per hr are common. This, it will be noted, is equivalent to 3000 per cent on the old basis of rating. In fact, the figure is so large that the phrase "per cent of rating" has long since been abandoned, and steam generating units are

* From an address at the Annual Convention of the National Association of Power Engineers, St. Louis, Mo., August 15, 1950.

now rated in thousands of pounds of steam per hour; although, with high pressure and with re-superheat, there are now some who prefer a kilowatt designation or million Btu per hour input in the fuel fired.

An outstanding factor has been the marked advance in the art of boiler-water treatment. Here a debt is owed to the chemist. The problems of water, including those of caustic embrittlement, the deposition of heavy scale inside the tubes, corrosion and even carryover of solids through the superheater have been largely solved. In 1920, the typical boiler operator was his own chemist, but in 1950 it is sometimes difficult for some of us even to understand the terminology that the chemist uses. However, as fast as the chemist develops new water technique the boiler designer takes full advantage of it.

Another significant development, for which we owe much to the boiler manufacturer and particularly to the metallurgist, is the design of boiler parts for high heat absorption coincident with increases in pressure from 200 psi to over 2000 psi, and in superheat temperature from a comfortable 500 F up to 900, 1000 and 1100 F. This, of course, leads to higher plant efficiencies and to better use of the steam generating unit, although it places a heavier duty on the boiler metal. This, however, has been splendidly met.

Tube Replacement by Welding

Early boiler designers always had to consider carefully the problem of replacing boiler or superheater tubes. Space was charted out in the boiler house into which tubes could be withdrawn so that a damaged tube might be readily replaced. This was frequently a difficult job, snaking a new tube in and out of a furnace. Now, welding repairs have developed to such an art that the damaged section of a boiler or superheater tube may be cut out and a new short piece welded in its place. This procedure is so much simpler than pulling out the whole tube that the designer now usually considers only the problems of initial erection and is rarely concerned with that of clearance or openings for tube removal.

As feedwater temperatures progressively increased there was less and less work for the boiler proper, with the result that its convection heat-absorbing surface has disappeared to the point where the modern large utility unit consists of a water-walled furnace, a superheater, an economizer and an air heater.

The heart, then, of such development has been the water-wall furnace, beginning with a cautious row of slag tubes across the pulverized coal furnace bottom in the early Twenties, followed by the installation of vertical tubes all carefully shrouded by refractory surfaces, to the modern design that has gone completely to bare water-wall tubes forming a solid wall around the entire furnace perimeter. The early belief that a furnace must be hot in order to insure ignition and complete combustion of the pulverized fuel (or spreader stoker coal or oil) was long ago abandoned in favor of the conception that the principal job of a furnace, in addition to absorbing radiant heat, is to cool the combustion gases, before leaving the furnace, to the point where the ash or slag will be so chilled as not to adhere to the heat-absorbing surfaces.

So firm was the conception of the three "T's" of combustion, namely, Time, Temperature and Turbulence, in the minds of all of us that this was a very slow development indeed. Many years ago, however, at our Cahokia plant in East St. Louis careful tests convinced us that temperature was not needed to obtain good and quick ignition of a pulverized fuel gas stream. It was also found that with good mixing of the coal and air in the burner, combustion was extremely rapid and very complete. The elements of time first seemed to lose importance and then temperature. Furnace design is now centering around sufficient water cooling surface to absorb the radiant heat and to achieve the required relatively low furnace exit gas temperature. For Illinois coals this temperature is usually from 2000 F to not more than 2100 F. Further, so skillfully has the designer calculated the water circulation through these great masses of furnace-wall tubes and the downcomer capacity of the cooler water lines outside the boiler that we no longer hear of starved furnace-wall tubes burning or blistering. Their record of performance and dependability even when operating at 3000 per cent of the old boiler rating has been remarkably good.

Since all coal and even oil contains ash, soot blowers are an important adjunct. These have been greatly improved in recent years by employment of mass blowing. Finally, the use of steam or of air in a puff system with automatic sequential pushbutton control has so simplified and improved the performance of soot blowers that the requirement of clean surfaces for high efficiency has largely been solved.

Part of the reason for good fuel ignition, even in a cold furnace, and ability to pulverize wet coals, is the high air temperatures now being supplied to the pulverizers. Air temperatures of 550 to 700 F are common. A particularly important point in the tubular-type air heater is its division into two sections so that the cold end contains short length tubes that can be readily replaced. This is particularly significant with flue gas temperatures under 300 F, as mentioned later.

With these developments the design of large steam generating units up to and in excess of 1,000,000 lb of steam per hour has become commonplace. The problems involved in the design of such large units to provide for expansion, support and structural strength are, of course, complicated; and the fabrication of a 60-in. drum 40 ft or longer is a masterpiece.

Coal preparation in high-capacity mills with good pulverization sustained over a wide range and long life of wearing parts must also be given credit. Fine pulverization is essential for quick ignition, complete combustion, and for avoiding sticky particles of ash, called "sparklers," carrying into the boiler passes; also for avoiding the deposition of heavy cinders on heating surfaces.

Quick ignition of pulverized coal (as well as gas or oil) must be credited to the modern burner which, to use a familiar term, can be thought of as a "carburetor" in which the fuel and air are adequately mixed. With the right mixture, rapid and sustained ignition results, and the danger of surges or loss of flame or furnace "puffs" has been to a large extent eliminated.

Finally, we come to the last, or twelfth, point of the trends in boiler design which seem to have been accomplished, namely, high efficiency and practically smokeless combustion. This has definitely been accomplished and efficiencies of 86 to 91 per cent are common.

The Second Twelve Points

Now as to points of design that have been attained to

some extent or are reasonably certain of achievement and wide adoption. As boiler capacities increase, the furnaces tend to become larger and the walls to become further and further away from the burning gas stream. This makes cooling of the furnace gases more difficult. One design that effectively takes care of this problem introduces a solid bank of tubes down the middle of the furnace, dividing the latter into two separate compartments, and bringing the water-tube surfaces closer to the burning gas stream. This is a feature incorporated in two boilers now being installed in the fourth section of our Venice Power Plant which will go into operation within the next few weeks. These are huge boilers expected to produce around a million pounds of steam per hour.

With higher steam temperatures it is important that the desired superheat be maintained over a fairly wide range of load. The single-boiler, single-turbine arrangement is well adapted to resuperheating steam that has passed through the higher turbine stages.

With steam temperatures of 900 F and over it is important that the superheater elements be in contact with furnace gases which are at least 2000 F, and this means that at high ratings superheat may be excessive. Typical methods of control have been either to desuperheat the steam by water spray, or to bypass some of the gases around superheater surface. The spray attemperation may require as much as 5 per cent of boiler feed to go to the superheater directly. Another very effective method of accomplishing this same result is employment of the tilting-type burner for pulverized coal, gas or oil. This burner is incorporated in corner tangential firing with the burners tipped slightly down or nearly horizontal for holding the superheat at high ratings; and with the burners gradually tilting upward by automatic control at lower ratings, reaching a maximum elevation for lowest rating. With this design it is possible to control the temperature of the furnace exit gases and thereby control superheat over a wide range; also to control resuperheat with only a negligible amount of water spray.

It is important to keep in mind the power consumed by auxiliaries, the chief of these being the induced-draft fans. It is particularly important, consequently, to minimize draft loss by elimination of baffles and passes through the boiler. This has been done in some later units. Whereas we have boilers of 400,000 lb of steam per hour capacity with 16 in. draft loss, the latest units at Venice require a total draft of only 13 in. The saving in power and in tip speed of the induced-draft fan with improvement in the life of the induced-draft fan blades is significant. Incidentally, the elimination of the boiler passes has also avoided the necessity of placing hoppers at the bottom of these passes to catch and remove cinder or ash particles.

Another significant development in eliminating the problems of ash adhesion, as well as erosion of boiler tubes, has been reduction of gas velocities entering the boiler and superheater passes while still at a high temperature. Much has been accomplished in this direction. Whereas these velocities were as high as 125 ft per sec a few years ago, they are now down in the order of 25 ft per sec. This has been accomplished by wider spacing of the first-pass tubes.

Production of good, clean, steam must be mentioned. The development of centrifugal or whirling-type steam scrubbers which thoroughly remove water from the steam are particularly significant. They have resulted not only in low carryover but they have permitted the reduction of the typical large boiler design from four, three, or two, down to one steam-water drum. Lower boiler costs have thereby resulted.

In the interest of high efficiency lower flue gas temperatures are now being employed. Temperatures from 280 to 250 F are not uncommon. The introduction of the replaceable short length of air heater tubes in the cold section has already been mentioned and facilitates repairs if corrosion does occur at such low temperatures. Experiments are also under way for introducing corrosion-resistant materials in these short lengths of tubes, aluminum and even stainless steel being used.

Another highly significant development that gives promise is that of the pressurized furnace. None of these are being installed in St. Louis but installations have been reported elsewhere. The pressurized furnace aims to eliminate the need for an induced-draft fan with all its problems of cost, space, power consumption, wear, and outage.

A pressurized furnace appears particularly promising in connection with outdoor boiler installations where the slight escape of gases through the setting would not be a handicap to operation. The outdoor or semi-outdoor installation not only greatly reduces the building cost, but also makes the boiler operating room a more comfortable place in which to work because the large surfaces radiating heat are out of that area.

Advances in Fly Ash Collection

Control of ash escaping up the stack has received a great deal of attention. Two means have been employed to solve this problem. One is the development of a dependable high-efficiency dust collector with efficiencies in some cases in excess of 95 per cent. Some installations are anticipating 97 per cent. The other is the introduction of the cyclone furnace which, with a dust collector of 50 to 80 per cent efficiency, is said to meet the A.S.M.E. fly ash code with higher ash coals.

Range in steaming capacity is receiving more attention. While high sustained ratings have been made possible, low load operation has not been so thoroughly worked out. High air temperatures with good, quick ignition will probably help at low loads. Lower superheat at low loads is usually not objectionable because the loss of efficiency is then less important, and lower temperature steam may actually help cool the low-pressure turbine blades at extremely low loads.

Development of the single-boiler design for large turbines greatly facilitates the use of remote, centralized control of both the turbine and boiler from one location. This can be placed in a separate, perhaps air-cooled room, with complete indication by instruments of all the factors of operation. This permits much more dependable operation and eliminates the difficult and sometimes impossible problem of communication between the boiler-room and turbine-room operators. The new Meramec Plant of our company will probably have such a central control room. Such additions to dependability, to the comfort of operators, and to the safety of the plant are highly desirable.

New Coal-to-Oil Plant Nears Completion

Completion of the major construction contract on the Bureau of Mines gas-synthesis demonstration plant at Louisiana, Mo., an 80- to 100-bbl a day unit that will convert coal to oil by a modified Fischer-Tropsch process, has been announced by the Secretary of the Interior. Integrated operation is scheduled for early in 1951.

First of its type in this country, this plant was built under the Bureau's synthetic liquid fuels research and development program to translate laboratory data into cost and engineering information directly useful to industry in planning, building, and operating commercial-scale installations.

This demonstration plant, the second built at Louisiana, Mo., will gasify pulverized coal with oxygen and superheated steam and then convert the resulting synthesis gas—a mixture of carbon monoxide and hydrogen—to liquid fuels by passing it over a catalyst. With American modifications, the Fischer-Tropsch process is said to be well adapted to the production of a good grade of motor gasoline and an excellent diesel fuel. Available by-products include alcohols, wax, aliphatic acids and hydrocarbon gases. Any rank of coal from anthracite to lignite may be used. In Germany, the use of this process increased gradually until January 1944 when the capacity of the Fischer-Tropsch plants reached a wartime peak of 10,000 bbl of product daily.

The first demonstration unit completed by the Bureau of Mines at Louisiana, Mo., the 200- to 300-bbl a day hydrogenation demonstration plant, has been in experimental operation since early in 1949. It employs another basic process (Bergius) of German origin for converting coal to liquid products ranging from high-octane aviation gasoline to heavy fuel oils. This process is applicable to all coals except anthracite and low-volatile bituminous and was used by the Germans to produce most of their wartime aviation gasoline.

The new gas-synthesis demonstration plant, incorporating advances made in the Bureau's broad research program, consists of five units: (1) oxygen production; (2) coal gasification; (3) gas purification; (4) hydrocarbon synthesis; and (5) distillation or product recovery and refining. Standard equipment was used wherever possible throughout the plant. Special designs were required in some instances, where there was little or no precedent in American industry, however.

Coal gasification is not only the first step in both basic processes for the production of synthetic liquid fuels but the ranking cost problem now requiring solution in obtaining gasoline and oil from coal. In the Fischer-Tropsch process, the synthesis gas obtained thereby constitutes roughly 60 to 70 per cent of the cost of the liquid fuel products. In the coal-hydrogenation process, the hydrogen obtained in part by gasification now represents 40 per cent of the product cost. For this reason, the Bureau is concentrating a substantial part of its research on various phases of this problem.

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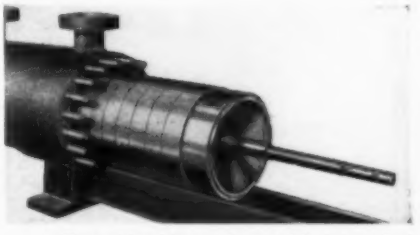

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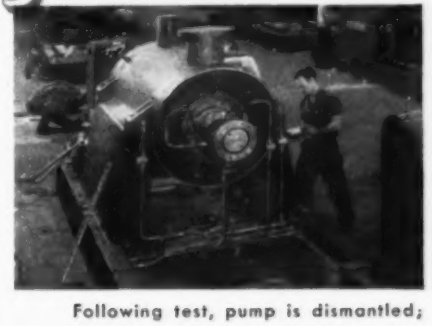

Following test, pump is dismantled; checked; inspected; reassembled.

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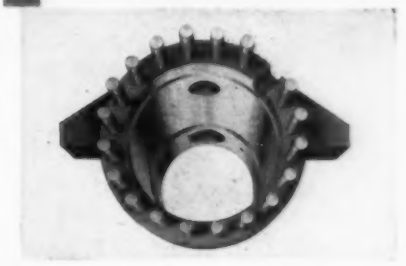

The outer case is precision finished.

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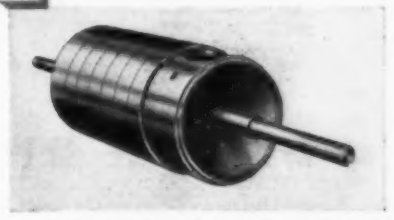

The unitized internal assembly is assembled outside the case. All parts are precision finished.

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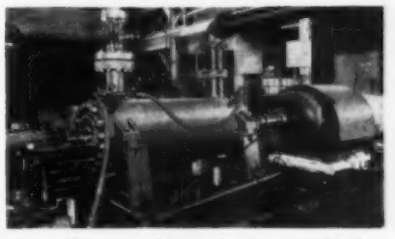

The pump is completely assembled—then performance tested.

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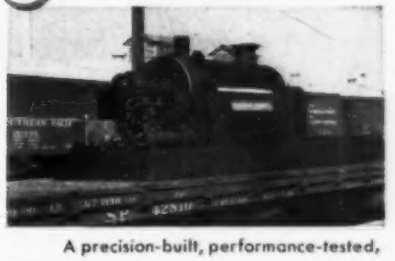

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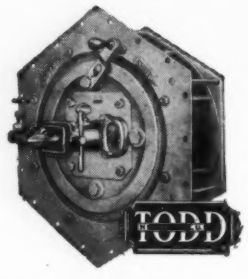

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Power Show to Feature Smoke Control Equipment

Current efforts to activate New York City's smoke control ordinance lend special interest to the 19th Exposition of Power and Mechanical Engineering, which will be held in Grand Central Palace Nov. 27 to Dec. 2. Plans for the exposition are far advanced and many of the exhibits will deal with fuels, fuel handling and combustion, as well as others showing improvements aimed at the suppression of fumes and dust.

This year's exposition will be held under the auspices of the American Society of Mechanical Engineers, which has been interested in smoke control for many years and has issued a model smoke law that has been studied and used as a basis for smoke ordinances by more than a hundred cities.

Many owners and operators of large and small power and heating plants have awakened to the need for modernization of their equipment as new enforcement rules begin to take effect and will be particularly interested in the smoke-indicating instruments which make it possible for the fireman or operator to know at all times the appearance of any smoke omitted from the stack. Another group of exhibits will consist of dust-separating equipment, applicable to pulverized-coal and spreader-stoker firing. A new type of equipment, the principle of which is in high repute in Europe, will be seen for the first time at the exposition. This utilizes the inertia of the dust particles, in conjunction with the aerodynamic forces in the draft, to produce a highly efficient separation through a series of fine louvres in a cone-shaped filter element.

"More Power to America Special" Starts Second Lap

The "More Power to America Special," the General Electric Company's mammoth mobile showcase of electric products for industry, headed west from Schenectady Sept. 5 on the second lap of its nationwide tour.

The ten-car exhibit train is scheduled to visit 29 key midwestern industrial centers this fall before swinging south, down the Atlantic coast.

The train has been undergoing routine maintenance and cleaning since completing its spring tour of New York and New England, during which twenty cities were visited and nearly 2000 miles covered. It is anticipated that by the end of its trip across the country in 1951, the streamliner will have visited 150 industry centers and been inspected by approximately 200,000 leaders of industry.

Because the exhibits aboard the train were designated especially to interest those concerned with the generation and industrial application of electricity, the train is not open to the general public. Attendance is limited to invited representatives of electric utilities, the manufacturing and transportation industries, the armed services, the federal government and municipalities.

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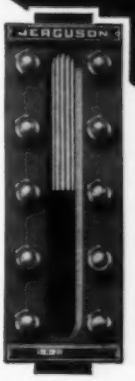

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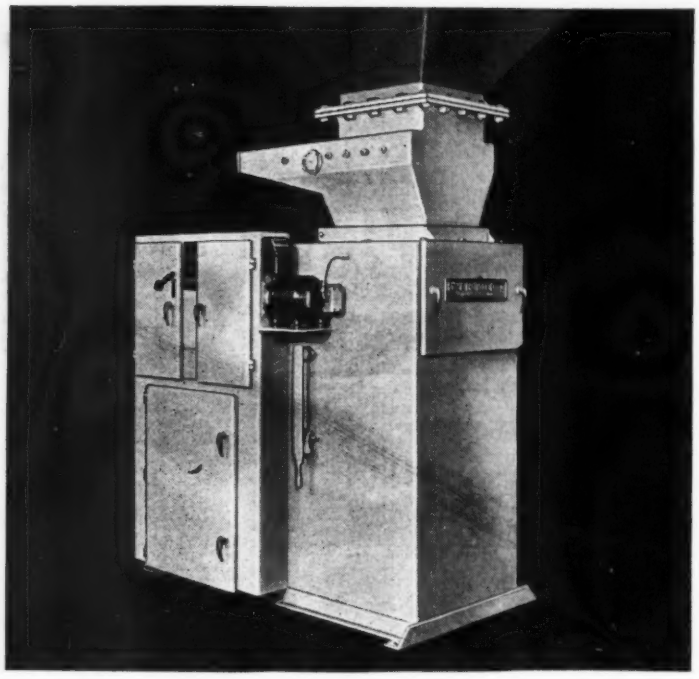

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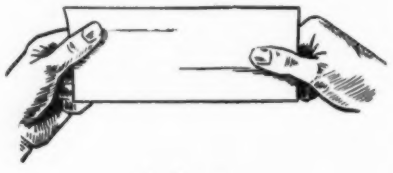
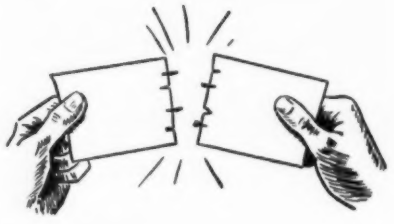


Now cut two pieces 3" wide by 5" long and join them together with staples. Pull this spliced strip just a little and it pulls apart.



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Annual Water Conference Program

The Eleventh Annual Water Conference of the Engineers' Society of Western Pennsylvania will be held October 16 to 18, inclusive, at the William Penn Hotel, Pittsburgh. The program is as follows:

Monday Morning

"Dianodic Method for the Control of Pitting and Tuberculation in Cooling Water Systems," by H. L. Kahler, Director of Research, and Charles George, Research Chemist, W. H. & L. D. Betz Co.

Monday Afternoon

"Electroplating Waste Disposal at the Westinghouse Electric Corporation Plant at Beaver, Pa.," by J. K. Rice, Cyrus Wm. Rice Co.

"Separation of Oil-Waste and Water Waste," by E. G. Kominek, Infilco Inc.

Tuesday Morning

"High-Pressure Boiler Feed Water Treatment, Evaporators vs. Demineralizing and Silica Removal," by V. J. Calise, Technical Director, Graver Water Conditioning Co.

"Vapor Purity to be Expected," by R. M. Buchanan and A. A. Pace, Duquesne Light Co., Pittsburgh, Pa.

Tuesday Afternoon

"Sampling of Steam for the Determination of Purity," by B. J. Cross, Manager, Research Department, Combustion Engineering-Superheater Inc.

"Economic Comparison of Methods of Control of Carbon Dioxide in Steam Condensation," by R. Rupert Kounty and Thomas B. Kneen, Pennsylvania State College.

Wednesday Morning

"Experimental Studies of Boiler Scales at 2400 psi," by J. A. Holmes, and C. Jacklin, National Aluminate Corp.

"Initial Report of Operating Data from Industrial Mixed Bed De-ionizing units," by W. S. Morrison and F. H. Kahler, Illinois Water Treatment Co.

Wednesday Afternoon

"Hot Lime Treatment Followed by Sodium Zeolite," by S. B. Applebaum, Cold Process Division, Cochrane Corp.

"Evaporator Feedwater Treatment at Sewaren Generating Station," by J. R. Denton, Worthington Pump & Machinery Corp. and R. I. Smith, Public Service Electric & Gas Co.

Welding Society Meeting

The 31st Annual Meeting of the American Welding Society will be held at the Hotel Sherman, Chicago, during the week of Oct. 22. The scheduled technical program includes some seventy papers in sixteen sessions. A number of these sessions will be devoted to specific industries, some of military significance such as ship construction, aircraft, piping, pressure vessels, railroads and machinery; others will cover

late developments and research in resistance welding, automatic welding, inert gas shielded-arc welding, and gas cutting. Still another group will deal with weldability, education, surfacing, flame hardening, electrodes, controls, inspection, research and nonferrous welding.

Among the papers on pressure vessels at the Oct. 26 morning session will be one on "Stress Concentration Problems in Welded Construction at Atmospheric and Elevated Temperatures," by G. J. Green and D. H. Marlin of Dravo Corp.; "Multiple Layer Submerged Arc Welding of Pressure Vessels," by L. C. Stiles and D. H. Curry of Chicago Bridge Co.; "General Procedure for Fabrication of Pressure Vessels," by S. V. Williams of A. O. Smith Corp.; and "Welding Stainless Steel Containers to Meet Sanitary Standards," by P. H. Mounts of Cherry-Burrell Corp.

At the session on pipe fabrication on the morning of Oct. 24 the following papers will be given: "Development of Welding Procedure for High-Pressure, High-Temperature Steam Piping," by N. L. Navarre, U. S. Naval Engineering Experiment Station; "Fabrication and Welding of High-Pressure, High-Temperature Alloy Piping," by H. J. Irrgang, Jr., of W. K. Mitchell & Co.; "Design and Installation of Large-Diameter, Long-Span, Welded Pipe," by Horace Jackson of Thompson Pipe and Steel Co.; and "Welding of 347 Stainless Steel," by R. W. Emerson of Pittsburgh Piping & Equipment Co.

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One man *at one point* controls the System.

The coal arrives by rail, is dumped into hoppers, conveyed by Beaumont Belt Conveyors and discharged either into a bunker for immediate use or down a chute to storage. In the yard, the coal is spread into compact layers—eliminating air pockets and minimizing the hazard of spontaneous combustion.

Tailblocks maneuver the Beaumont Drag Scraper which is operated through remote control. By means of backhaul towers, the coal can be stored to heights of over 100 feet. Beaumont supplies and installs the complete conveying and storage systems—in capacities from 10 to 300 tons per hour.

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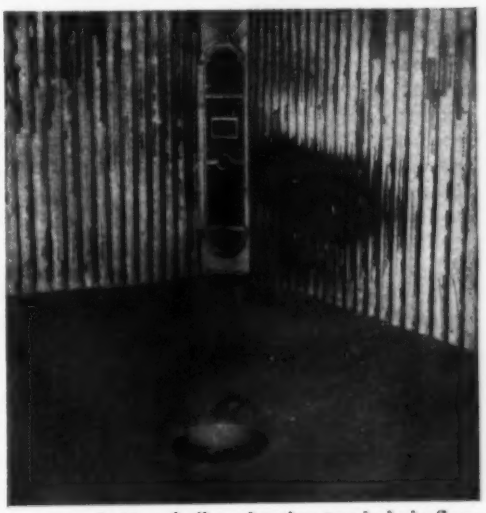
A large refinery plant was taking the time and trouble to replace the floors of their boiler by pounding a refractory in place. The average life of the floor was 44 days.

Then they switched to R & I Moldit Chrome, a castable refractory, which when mixed with water can be poured, troweled, shoveled or shot in place like concrete. Considerable installation time was saved and a service check at end of 96 days showed the Moldit Chrome still in good condition.

Many plants are now using this castable for both floors and walls of oil and coal-fired boilers. No pounding or ramming is needed and the life is longer.

Ask your supply house for R & I Moldit Chrome. Write us for Bulletin R-48.



Slagging bottom boiler, showing tap hole in floor where slag runs out. Moldit Chrome was shot over tubes in floor.

R&I

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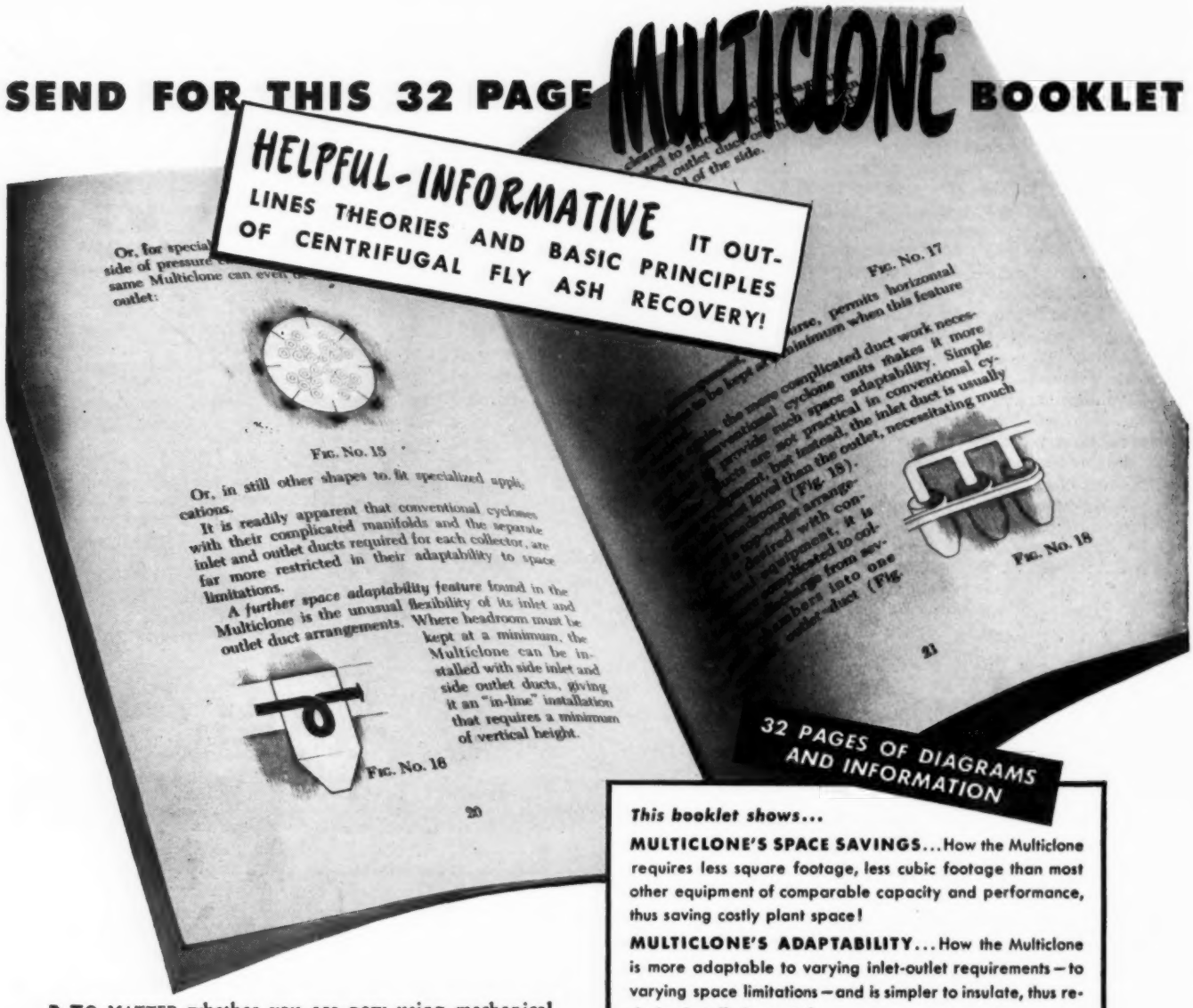
SEND FOR THIS 32 PAGE MULTICLONE BOOKLET


HELPFUL-INFORMATIVE IT OUTLINES THEORIES AND BASIC PRINCIPLES OF CENTRIFUGAL FLY ASH RECOVERY!
FIG. No. 15
Or, in still other shapes to fit specialized applications.
It is readily apparent that conventional cyclones with their complicated manifolds and the separate inlet and outlet ducts required for each collector, are far more restricted in their adaptability to space limitations.
A further space adaptability feature found in the Multiclone is the unusual flexibility of its inlet and outlet duct arrangements. Where headroom must be kept at a minimum, the Multiclone can be installed with side inlet and side outlet ducts, giving it an "in-line" installation that requires a minimum of vertical height.
FIG. No. 16
20
FIG. No. 17
FIG. No. 18
21
32 PAGES OF DIAGRAMS AND INFORMATION

This booklet shows...

MULTICLONE'S SPACE SAVINGS...How the Multiclone requires less square footage, less cubic footage than most other equipment of comparable capacity and performance, thus saving costly plant space!

MULTICLONE'S ADAPTABILITY...How the Multiclone is more adaptable to varying inlet-outlet requirements—to varying space limitations—and is simpler to insulate, thus reducing installation costs!

MULTICLONE'S EFFICIENCY...How Multiclone's multiple *small diameter* tubes, made possible by its exclusive vane design, give higher centrifugal forces and more complete cleansing of *all* suspended particles—even small ones of 10 microns and less!

MULTICLONE'S LOW MAINTENANCE...How the Multiclone has no high speed moving parts to repair or replace, no pads or filters to clean or renew, nothing to choke gas flow or increase draft losses as suspended materials are recovered. Multiclone draft losses remain uniformly low—recovery efficiencies uniformly high—at all times!

Make sure that a copy of this helpful booklet is in your reference files by sending for your copy now!

NO MATTER whether you are now using mechanical dust recovery equipment or are planning the installation of such equipment at some future date, here is a booklet that is full of helpful and valuable information on centrifugal dust recovery. It not only explains the basic methods and principles involved, but also shows the important differences between small and large diameter separating tubes, shows how to simplify your duct work and reduce installation costs, and outlines many other important factors to be considered in selecting mechanical dust recovery equipment.

In addition, this informative booklet illustrates and explains how MULTICLONE'S unique *vane* design is fundamentally different...how it makes possible greater compactness, simpler installation, high recovery of the small particles as well as the medium and coarser ones, and many other facts on MULTICLONE advanced design.

A limited supply of these booklets is available for free distribution to those interested in mechanical recovery equipment and methods. Write for your copy today.

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NEW EQUIPMENT

Boiler Feed Pump

A new single-suction, double-case, barrel-type boiler feed pump designed for operation in the 1200- to 2500-psig pressure range has been announced by Allis-Chalmers Mfg. Co., Milwaukee. The new unit has back-to-back, impellers and radially balanced double volutes in a split inner casing. In addition to its high efficiency, the pump provides the stability of a volute design, complete radial and axial balance, freedom from expansion in any direction and accessibility for maintenance.

Power-Station Auxiliary Motor

A new modified base-ventilated motor, having ratings ranging from 200 to 3000 hp and suitable for driving power station auxiliaries mounted out of doors, has been made available by General Electric's Small and Medium Motor Divisions. It is designed to be mounted on a concrete base which is raised sufficiently from the ground to allow contaminated ambient air to flow through the foundation at high velocity. Ventilating air enters the motor through a vertical passage in the base and is pulled from the ambient air stream at low velocity. After circulating through the motor the ventilating air is exhausted from the top.

Control Drive

The Bailey Meter Company, Cleveland, Ohio has developed a completely enclosed air-operated drive which makes it possible to parallel characteristics of a driven device with characteristics of other equipment, thereby securing a unified system. Known as the "Characterized" control drive, it consists of a double-acting air cylinder, a positioning relay, and a manual operating wheel or lever.

Double-Union Gage Valves

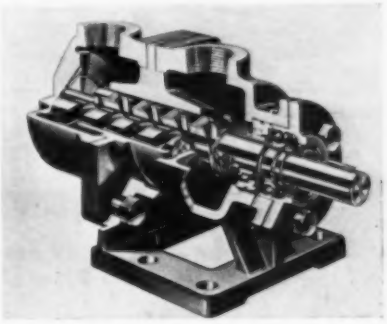
Three new double-union gage valves have been announced by the Jerguson Gage & Valve Co., Somerville 45, Mass. Their design and construction incorporate a union connection to both the gage and the tank or vessel, making it possible to turn the gage in any desired angle or to remove it quickly and easily without removing the valves or draining the liquid from the vessel. Among the features are plain or quick closing, stainless steel trim, and interchangeable unions, nuts and tailpieces.

High-Pressure Expansion Joints

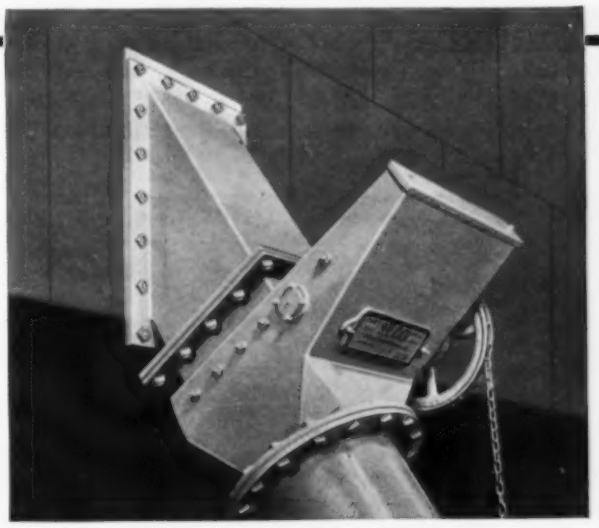
The "Flexoniflex" line of expansion joints produced by the Chicago Metal Hose Corp., Maywood, Ill., is intended for axial, offset and radial motion control in high pressure piping systems. The joints consists of corrugated, bellows-type sections of stainless steel or other alloys formed within integral control rings and end sections. They are manufactured with single or multiple plies and may be lined or unlined, depending on application. Sizes vary from $^{5}/_{8}$-in. I.D. on through the range of high-pressure pipe sizes, with allowable temperatures from subzero to 1400 F for stainless steel. Units have been designed for service well in excess of 1000 psig.

Rotary Pumps

The Imo Series A313A pump, manufactured by the De Laval Steam Turbine Co., is designed for pumping petroleum products and other light or viscous fluids in volumes to 85 gpm against pressures up to 150 psig, as required for rotary and steam atomizing oiler burners, oil transfer, lubrication and hydraulic systems. It



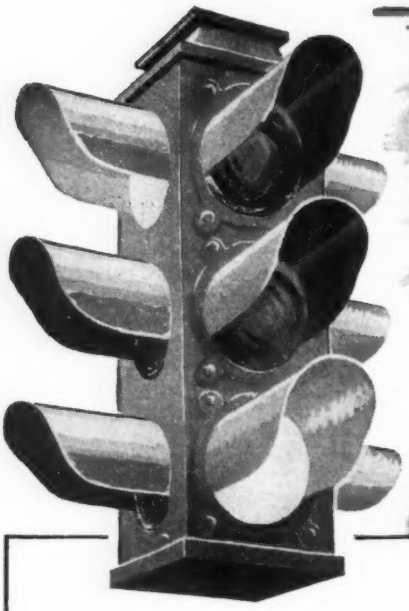
may be direct connected to its driver, and all parts are interchangeable. The mechanical seal is said to require no attention. Suction can be located at top, bottom, horizontal left or horizontal right and the pump can be mounted in any desired position.



S-E-CO. COAL VALVES can be made for installation in an inclined position, as shown in photograph. In some plants if coal valves are installed in this position, a considerable saving in headroom results. These valves are equipped with a disc brake so that they are not self-closing.

Your inquiry would be appreciated.

STOCK EQUIPMENT COMPANY
715C Hanna Building ★ Cleveland 15, Ohio



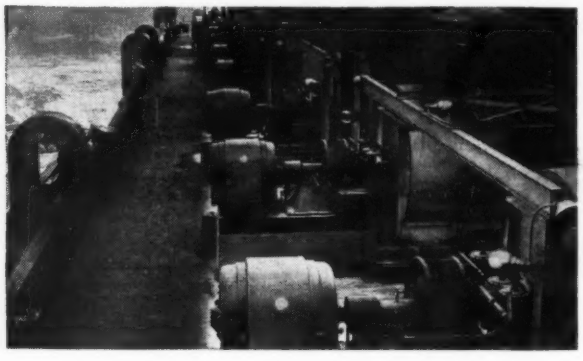
DRAFT FANS GO on GREEN

A Big Draft Job Handled Capably by Green Fans

Twenty-four large Green Fans take care of a heavy draft load at the Venice (Illinois) Plant of the Union Electric Co. of Missouri. Each of six boilers has two sets of Green Fans, each set consisting of one induced draft fan and one forced draft fan coupled to one motor as a unit. With the heavy demands on this station, all boilers are usually in service continuously, thus throwing an unrelenting burden on the fans.

Engineers whose responsibility it is to recommend or accept draft fans for large power plants certainly want efficiency and low operating costs. But they don't overlook the maintenance and replacement angles. They want the sound designs of competent experienced fan engineers. They also want the care in construction that is found in shops of a company that has built up an international reputation as the "authority" on draft fans. They know that such a company will not tolerate sloppy shop work.

Green is this authority on mechanical draft fans.



Have You a Copy of Our Fan Bulletin No. 168? If not, we shall be glad to send you one.

THE GREEN Fuel Economizer COMPANY INC.

BEACON 3, NEW YORK

ECONOMIZERS • FANS • AIR HEATERS • CINDERTRAPS

New Catalogs and Bulletins

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Conveyors

Pioneer Engineering Works has issued an attractively illustrated 52-page booklet on its line of "Continuflo" conveyors. Printed in two colors and including many conveyor photos and job applications, the booklet provides information on selecting conveying equipment, including correct angle of incline, spacing of idlers and motor horsepower required.

Vibrators

Two new bulletins prepared by the Robins Conveyors Division of Hewitt-Robins Inc. describe the "Vibra-Feeder" and the "Vibra-Veyor." The former employs mechanical operation and requires a ½-hp motor, and the latter produces balanced mechanical operation without counterweights. It is claimed that a single vibrator can activate up to 200 feet of pan length.

Stokers

A 16-page catalog entited "The Stowe Stoker Story" has been prepared by the Johnson & Jennings Co., division of Pettibone Mulliken Corp. It describes design and operating features of the equipment, includes a cutaway sectional view, and provides pictures of typical installations.

Communication Systems

Gai-Tronics Corp., subsidary of Gilbert Associates, Inc., has published an informative 40-page booklet entitled "Power Plant Communication Systems." Based on extensive studies of the requirements for swift and intelligible communication in modern central-station operation, the booklet should prove of interest to both designers and operating companies. Its value is increased by the inclusion of photographs showing details of the communication equipment as well as representative locations in a typical power plant.

Liquid Level Indicators

20-page Bulletin WG-1823 describes liquid level indicators and auxiliary attachments manufactured by Yarnall-Waring Co. for remote indication of liquid level in boilers, feed-water heaters, and storage tanks. Included are complete details of construction and operation, installation suggestions, dimensions, application diagrams, pictures of typical installations, and procedures for specifying and ordering.

Steam Traps

The C. E. Squires Co. has printed a 4-page bulletin containing information

on steam and air traps, including capacity tables and sizing information. Other products described include "venturo-valves," reducing and regulating valves, governors, and feedwater controls.

Rotating Equipment

A 24-page booklet on "Care of AC Rotating Equipment" has been released by Allis-Chalmers Manufacturing Co. The principal topics covered are preventive maintenance and machine repair, with emphasis placed upon care of bearings, vibration problems, effects of expansion and contraction, and balancing rotating equipment.

Cast Steel Valves

The Wm. Powell Co. has prepared a 6-page bulletin describing a new line of small-size, high-pressure cast-steel valves designed for such services as high-pressure steam, boiler feedwater, and instrument use. They are available in globe, angle and "Y" patterns, 1500 and 2500-lb classes, in sizes from $^1/_2$-in. to 2-in. inclusive.

Water Hardness Tests

The extremely rapid, simple and accurate "one-minute" tests for determining water hardness are described in Bulletin 1RE50 just issued by Hall Laboratories. Procedure, reagents and equipment for the tests are pictured and described, the accuracy of which are said to have been demonstrated within 1 ppm.

Speed Reducers

Imo-DeLaval worm gear speed reducers are the subject of a well-prepared 32-page bulletin covering the latest revised AGMA horsepower ratings. The bulletin describes manufacturing operations for speed reducers, lists various types, and includes selection tables, horsepower ratings, overhung load ratings, and typical dimensions. There is also a section describing vertical speed reducers for cooling tower service.

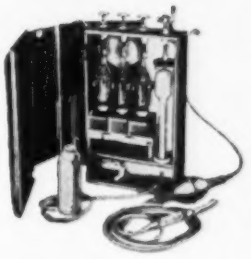
Gages and Water Columns

Bulletin DD prepared by Ernst Water Column & Gage Co. describes sight flow indicators for insertion in pipe lines, "Telflow" indicators, gage glasses and water columns, and other safety-first specialties. Dimension charts and price lists are included.

Steam Jet Syphons

Schutte and Koerting Co. has prepared a 24-page catalog describing its line of steam jet syphons. Section 1 of Bulletin 2-A details the design, application, construction and operation of the various types of syphons available. Special purpose and corrosion-resistant syphons are covered in Section 2. Typical applications of syphons in the pumping, heating and mixing of liquids and the handling of solids are included in Section 3. Detailed color drawings accompany the descriptive material.

Determine Combustion Efficiency By Accurate Measurement of CO_2



by hand

HAYS PORTABLE GAS ANALYZER

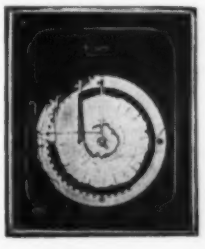
Every power plant needs this handy Hays Portable Gas Analyzer or Orsat. It gives you a quick, accurate test of flue gases for CO_2—one of the best known ways to measure the efficiency of your fire. It also serves as a check on your CO_2 Recorder.

Hays offers several styles from which to choose—from the single chamber to the multiple unit that analyzes for CO_2, O_2 and CO. All sizes immediately obtainable. Send for new catalog (Publication 47-668) and the helpful booklet "The A-B-C of CO_2."

or automatic

HAYS CO_2 RECORDER

To most boiler room operators this is the dependable "stand by"—the Hays CO_2 Recorder or Combustion Meter, permanently mounted and automatic. Every two minutes throughout the 24 hours it makes a combustion analysis and records its findings on a 10-inch chart. It also records draft and flue gas temperature. The Hays Combustion Meter operates entirely by water on the true Orsat principle of volumetric measurement and chemical absorption—and is virtually infallible. Its interesting story is in Publication 47-550—send for it.



The Hays Corporation, Michigan City 1, Ind.

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C-9-50

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Personals

Daniel B. Altman has joined the Kuljian Corp., engineers and constructors of Philadelphia, as head of its new Department of Management Engineering. Mr. Altman was formerly a partner in Hare, Bready & Co., following a number of years as an engineering consultant with Day & Zimmerman.

Rear Admiral Kenneth K. Cowart has been appointed for a four-year term as engineer-in-chief of the U. S. Coast Guard with headquarters in Washington, D. C.

Prof. H. I. Loberg has been appointed director of the School of Mechanical Engineering at Cornell University. He succeeds Prof. W. J. King who resigned some months ago.

Frederick C. Schlemmer, until recently manager of the Hanford Works of the Atomic Energy Commission, has been appointed manager of construction of Burns & Roe, Inc., engineers and constructors of New York City.

Birger H. Stolpestad has been promoted to chief engineer of Crosby Steam Gage & Valve Co., Wrentham, Mass.

Eric G. Peterson has been elected to the Board of Directors and made vice president of Peabody Engineering Corp.

Business Notes

Warren Steam Pump Co., Warren, Mass., has purchased the Quimby Pump Div. of H. K. Porter Co. of Pittsburgh, manufacturer of screw and rotary pumps.

General Electric Co. has announced a program for large-scale production of gas turbines for power generation and gas pipe line pumping stations. Accelerated production has already started on the first few of more than twenty such units scheduled for delivery within the next two years.

Hagan Corp. has established a new Los Angeles district office at 3931 Tweedy Blvd., South Gate, Calif. This office will also represent Bull & Roberts, which is associated with Hagan and its subsidiaries in the marine field.

Manning, Maxwell & Moore, Inc., has elected Hamilton Merrill president. He was previously vice president in charge of the Consolidated-Ashcroft-Hancock Div.; Chester H. Butterfield succeeds him in the latter capacity.

Graver Water Conditioning Co. announces the appointment of Evans L. Shuff & Associates as its representative for the Atlanta, Ga., territory; also appointment of James T. Potter of 1521 Stanford Pl., Charlotte, N. C., as its representative for North and South Carolina.

Edward Valves, Inc., has appointed the I. Russell Berkness Co. of Richmond, Va., as its sales and service representative for the State of Virginia.

Flexitallic Gasket Co. has recently added three new agents and one new distributor to its field organization. The

agents are The Metrol Co., Detroit, for the lower peninsula of Michigan and Toledo; Power Specialty Co. of Houston, Tex., which will serve eastern Texas and western Louisiana; and the Illes Power Control Co. of Cleveland, O., which will serve northern Ohio, east of the Toledo area. The new distributor is the Air-draulic Equipment Co. of Buffalo, covering western New York and Syracuse.

The Swartwout Co., Cleveland, has appointed Kenneth P. Hengesbach as power plant equipment sales engineer in the Company's Philadelphia District Office.

Peabody Engineering Corp., New York, has announced the appointment of William Godley as manager of contract sales, George E. Smith as manager of its Air Heater Div., and Edward R. Clark as manager of its Automatic Oil Burner Div.

The **Dampney Co. of America,** Hyde Park, Mass., has expanded its industrial sales representation with appointment of three new agents to handle its line of specialized protective coatings; they are Boiler Supply Co., Nashville, Tenn., which will cover central Tennessee; and R. E. Mundy Co., Roanoke, Va., which will cover central Virginia and southern West Virginia; and Consultores y Abastecedores Industriales, S. A., Dolores 17–301, Mexico, D. F.

Pacific Pumps Inc., Huntington Park, Calif., announces the appointment of John Wahlstrand as sales engineer with headquarters in the Houston Office of the company.

SAUERMAN FOR FAST MATERIAL HANDLING AT LOWEST COST

BETTER STOCKPILING THE SAUERMAN WAY

Faced with problems of storing more coal without using more labor, your answer is a Sauerman Power Scraper, requiring only one man at the controls.

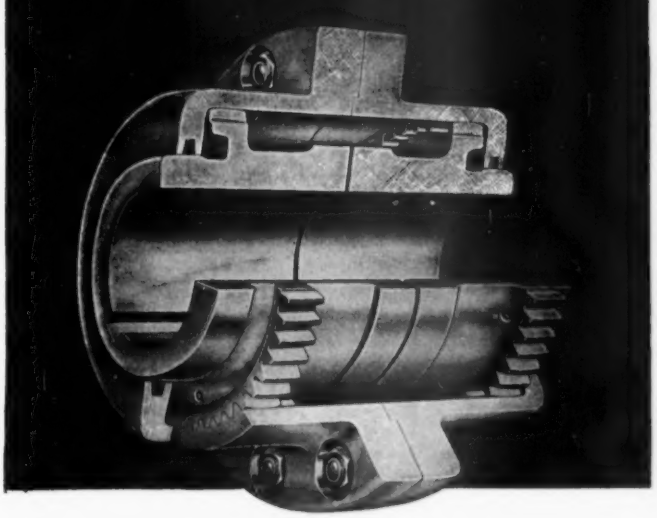
LET US SHOW YOU ACTUAL RESULTS. Hundreds of plants using Sauerman Systems, are storing and reclaiming coal at costs of only a few cents per ton. Coal piled higher in compact layers. No air pockets to promote spontaneous combustion. Far less dust and dirt.

Whatever your tonnage, large or small, a Sauerman Scraper can make important savings in handling costs. SEND FOR CATALOG.

The Sauerman scraper pictured above has served 22 years and seems ready for many more. It operates on a dock 1,000 ft. long and 400 ft. wide adjoining an industrial plant. The scraper spreads and stacks the coal brought in by cargo ships and reclaims as required to the plant.

SAUERMAN BROS., Inc.
550 SO. CLINTON ST. CHICAGO 7, ILLINOIS

POOLE

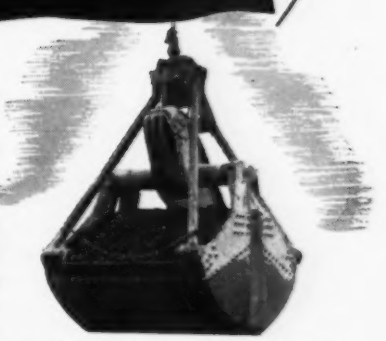


A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS
POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

BLAW-KNOX BUCKETS

Cut Fuel Handling Costs!



BLAW-KNOX Buckets cut costs because there's less dead bucket weight and more net pay load resulting from the practical use of light weight alloys.

Climatic conditions, gradation and type of fuel, method of handling from stockpile, boats or cars, definitely affect the extent to which the practical use of light weight alloys may be employed.

Experienced Blaw-Knox engineers are available to discuss your individual problems without obligation, or write for Bulletin 2229.

BLAW-KNOX DIVISION
of Blaw-Knox Company
2049 Farmers Bank Building • Pittsburgh 22, Pa.

BLAW-KNOX CLAMSHELL BUCKETS
FOR COAL AND COKE

for BOILER STEEL BRUSH-STROKE SECURITY

· · · AGAINST CORROSIVE ATTACK IN ANY OF ITS VARIED FORMS

· · · AGAINST BONDED DEPOSIT ACCUMULATION

To the problem of keeping internal boiler metal sound and clean, APEXIOR NUMBER 1 takes a simple, direct approach. With the stroke of a brush, it completely transforms boiler steel to a material inert to all waters at any temperature or pressure, to chemical cleaning or to standby, and highly resistant, as well, to deposit formation.

Metal thus stabilized teams ideally with the best in conditioned water for highest steam-generating efficiency—or, should variables cause temporary deviation from established standards, serves as compensating protection.

If you have not observed the superiority of APEXIORized steel, we suggest drum coating as a logical, inexpensive start to eventual surfacing of tubes, water walls, economizers, circulators, and associated power equipment exposed to steam and boiler water.

Simply clean (a quick Dampney test tells you when metal is ready for APEXIOR), paint, and place in service. Inspection at the next scheduled outage — and a comparison with bare steel — will tell you why consulting engineers specify APEXIOR NUMBER 1, boiler insurance companies recommend it, and operating engineers in thousands of central stations and industrial plants are long-time repeat-order purchasers.

Other specialized Dampney coatings provide external Boiler protection. For dry-heat service on fronts, casings, fire and inspection doors, and under insulation, ask for data on THUR-MA-LOX (black and aluminum) and Dampney Silicone Coating (aluminum).

MAINTENANCE FOR METAL

THE DAMPNEY COMPANY OF AMERICA

HYDE PARK, BOSTON 36, MASS.

100-1

A.S.T.M. to Study Sampling and Analysis of Atmospheric Pollution

The American Society for Testing Materials has authorized the formation of a new technical Committee on Sampling and Analysis of Atmospheric Pollution of which Dr. Louis C. McCabe, chief of Air and Stream Pollution, U. S. Bureau of Mines, has accepted the temporary chairmanship. This committee will not attempt to specify limitations of pollution, nor will it deal with such other related matters as biological and health problems; instead it will be concerned with the problem of developing analytical and sampling test methods as standards. The situation at present is so involved and to some extent chaotic that the work should be useful to all the interests involved. While much work has already been done on the various instrumentation angles, there continues a need for additional new and improved instruments. Much research is already under way in this field directed toward the development of instruments by which a single or a few contaminants will be measured. Studies are continuing in various channels on contaminants to be measured which will offer a true index of the nature and extent of pollution in an atmosphere.

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